DOE/RL-2016-19
Revision 0

Calendar Year 2015 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

DOE/RL-2016-19
Revision 0

Calendar Year 2015 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation

Date Published
August 2016

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
P.O. Box 550
Richland, Washington 99352

APPROVED
By Julia Raymer at 7:50 am, Aug 09, 2016

Release Approval   Date

Executive Summary

Interim groundwater treatment remedies are operating in the 100-HR-3, 100-KR-4, and 100-NR-2 Groundwater Operable Units (OUs). Hexavalent chromium (Cr(VI)), the primary contaminant of concern (COC) in the 100-HR-3 and 100-KR-4 OUs, is being addressed by pump and treat (P&T) systems under an interim remedial action. Strontium-90 is the primary COC in the 100-NR-2 OU and is being addressed using permeable reactive barrier (PRB) technology to immobilize the strontium.

The P&T systems in the 100-HR-3 and 100-KR-4 OUs extract groundwater and remove the Cr(VI) using an ion-exchange resin in treatment plants before reinjecting the treated water into the aquifer. A total of 5,499 million L (1,452 million gal) of groundwater was extracted and treated by the active P&T systems in the 100 Areas during 2015. These actions removed 159.7 kg (351 lb) of hexavalent chromium from the aquifer, described as follows:

- At the 100-HR-3 OU, the combined DX and HX P&T systems processed approximately 2,605 million L (688 million gal) of groundwater and removed 109.6 kg (241 lb) of Cr(VI). Since startup of the 100-HR-3 OU P&T systems, the cumulative volume of groundwater treated is approximately 15,542 million L (4,103 million gal), with 2,349 kg (5,168 lb) of Cr(VI) removed.

- Concentrations of Cr(VI) in 100-D Area groundwater have been decreasing significantly due to DX P&T system operations and source area removal of waste sites such as 100-D-100, and the combined 100-D-30/100-D-104 waste sites. In 2015, the maximum Cr(VI) concentration was 614 µg/L, compared to the maximum concentration in 2010 of 69,700 µg/L. This indicates a significant reduction in Cr(VI) mass in the unconfined aquifer. The areal extent of the plume at the remedial action target concentration of 20 µg/L Cr(VI) declined between 2014 and 2015. The extent of the high-concentration portions of the plume also declined. Removal of high-concentration plumes and elimination of continuing secondary sources is essential to achieving the ultimate groundwater cleanup goal.

- The 100-KR-4 OU remediation systems include the KR4, KW, and KX P&T systems. During calendar year 2015, a total of 2,894 million L (764 million gal) of groundwater was treated and 50.1 kg (110 lb) of Cr(VI) was removed. Since startup of the 100-KR-4 OU P&T systems, the cumulative volume of groundwater treated is approximately18,839 million L (4,973 million gal), with 836.4 kg (1,840 lb) of Cr(VI) removed. In 2015, four wells were drilled to support ongoing remedial process optimization activities at 100-K (199-K-203, 199-K-207, 199-K-208, and 199-K-209). Well 199-K-208 was put into service as an extraction well for the 100-KX P&T system in 2015. The other three wells were drilled to characterize and monitor specific conditions throughout the 100-K Area. Increased extraction rates resulting from the installation of new wells and realignment of existing wells over the last 2 years is providing enhanced plume control in near-river regions of the 100-KR-4 OU.

At the 100-HR-3 OU, in situ redox manipulation (ISRM) is used to produce a PRB for treatment of Cr(VI). This passive system reduces Cr(VI) to the immobile, nontoxic, trivalent form as it flows through an aquifer zone treated with sodium dithionite. A notice of non-significant change to the Record of Decision was issued in 2010,[1] which indicated that the barrier would no longer be actively maintained and P&T system expansion (i.e., extraction wells downgradient of the PRB) would be used to address breakthrough and provide a protective interim remedy. The ISRM PRB at the 100-D Area continues to operate, supplemented by P&T system extraction wells. At the end of 2015, concentrations at barrier wells ranged from below detection to 110 µg/L, with an overall decrease in concentrations compared to 2014. The observed changes in Cr(VI) concentration are attributed to a combination of residual chemical reduction by the ISRM PRB and extraction and treatment of contaminated groundwater in areas where the PRB is no longer effective.

Protection of the Columbia River against discharge of chromium-contaminated groundwater continues to improve. River protection is assessed against conditions that may cause the river interface area to exceed the 10 µg/L ambient water quality criterion. During 2015, only 300 m (985 ft) of the 2,800 m (9,186 ft) of affected shoreline in the 100-D Area was identified as not adequately protected. This reflected a substantial improvement in river protection along the northern portion of the 100-D Area. Of the

[1] 11-AMCP-0002, 2010, "Non-Significant Change for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision, Hanford Site, Washington, July 2010, Memo to File Regarding: Supplemental Actions for the In-Situ Reduction/Oxidation Manipulation Barrier Performance for the 100-HR-3 Groundwater Operable Unit Interim Remedy" (letter to J.A. Hedges, Washington State Department of Ecology, and D.A. Faulk, U.S. Environmental Protection Agency, from R.A. Holten), U.S. Department of Energy, Richland Operations Office, Richland, Washington, October 26. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1011290677.

4,400 m (14,435 ft) of affected shoreline in the 100-H Area, 500 m (1,640 ft) was identified as not adequately protected in 2015. There is no net change in length of affected shoreline identified as not adequately protected between 2014 and 2015. However, improved capture in areas previously identified where action may be required resulted in an additional 400 m (1,315 ft) of shoreline length identified as protected in 2015.

In the 100-K Area, 100 m (330 ft) of the 4,000 m (13,123 ft) of affected shoreline was identified as not adequately protected in 2015. This is a reduction from 200 m (655 ft) identified as not adequately protected in 2014. In both the 100-HR-3 and 100-KR-4 OUs, the improvements in river protection status are the direct result of ongoing improvements in capture and treatment of contaminated groundwater. Improvements in 2015 included increased extraction rates and placement of new extraction wells at locations selected to intercept targeted plume segments.

In the 100-NR-2 OU, interim remedial actions are implemented for strontium-90 and total petroleum hydrocarbon (TPH) groundwater COCs. A P&T system developed in the 1990s for the removal and treatment of strontium-90-contaminated groundwater proved ineffective; subsequently, a PRB was installed along the shoreline to treat the aquifer with the mineral apatite. An initial 91 m (300 ft) length of the barrier was installed from 2006 to 2008, and later expanded to 311 m (1,020 ft) in 2011, to target the shoreline downgradient of the highest strontium-90 groundwater plume contamination.
As groundwater flows through the barrier, strontium-90 contamination adsorbs to the apatite and is immobilized within the barrier, thereby reducing the amount of contamination migrating to the Columbia River. Groundwater samples at the PRB monitoring points show that the concentrations in the majority of the monitoring wells in 2015 were lower than preinjection levels by nearly 90 percent. However, in 2015 concentrations of strontium-90 have increased in some of the monitoring wells, and are close to preinjection levels in two monitoring wells.

Removal of TPH free product (primarily in the diesel range) from well 199-N-18 continued in 2015. The diesel is removed using a polymer “smart sponge” that selectively absorbs petroleum products from the groundwater within the well. In 2015, 1,050 g of diesel was removed from well 199-N-18. This annual summary report describes the operations and results of these groundwater treatment remedies during 2015. The goals of the remedies are to protect the Columbia River, protect human health and aquatic life, and provide information that will enhance remediation. Target *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement)[2] milestones have been established to ensure that the impact of Cr(VI), strontium-90, and other contaminants to the Columbia River and groundwater are remediated in a timely manner. The following four target date milestones are directly applicable to the 100 Area OUs:

- ***Milestone M-016-110-TO1 (December 31, 2012):*** *DOE shall take actions necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area National Priorities List [NPL] Operable Units to ensure ambient water quality standards for hexavalent chromium are achieved in the hyporheic zone and river column water.*

  The U.S. Department of Energy (DOE) continues to optimize groundwater remedies in the 100 Areas. Groundwater P&T systems in the 100-HR-3 and 100-KR-4 OUs show continuing improvement in river protection. In 2015, the 100-D Area exhibited a 60 percent increase in protected shoreline length and 40 percent reduction in unprotected shoreline length. The 100-H Area exhibited a 15 percent increase in protected shoreline length and no net change in unprotected shoreline length. The 100-K Area exhibited a 20 percent increase in protected shoreline length and 50 percent reduction in unprotected shoreline length in 2015.

- ***Milestone M-016-110-TO2 (December 31, 2020):*** *DOE shall take actions necessary to remediate hexavalent chromium groundwater plumes to ensure hexavalent chromium will meet drinking water standards in each of the 100 Area NPL Operable Units.*

  DOE's operation and enhancement of Cr(VI) groundwater remedies in the 100 Areas continued to reduce overall groundwater chromium concentrations. Plume areas exceeding drinking water standards have been substantially diminished in the 100-HR-3 and 100-KR-4 OUs.

- ***Milestone M-016-110-TO3 (December 31, 2016):*** *DOE shall take actions to contain the strontium-90 plume at 100-NR-2 Operable Unit to ensure the default ambient*

[2] Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=81.

water quality standard (8 pCi/L) is achieved in the hyporheic zone and river water column.

DOE has demonstrated the efficacy of a PRB to reduce strontium-90 releases to the river from contaminated groundwater at the 100-NR-2 OU. Plans are in place to expand the barrier treatment.

- **Milestone M-016-110-TO4 (December 31, 2016):** DOE shall implement remedial actions selected in all 100 Area Records of Decision for Groundwater OUs to ensure no contamination above drinking water standards enters the Columbia River unless otherwise specified in a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) decision.

  DOE will continue to address identified COCs in groundwater in the 100 Areas in records of decision. Final remedial actions will include all of the 100 Area OUs, and all groundwater COCs.

This report details the volume of water treated, the contaminant mass removed through the P&T systems, the efficiency of the P&T systems, the effectiveness of the PRBs, and the resulting effect on groundwater concentrations. These interim remedies were initially implemented in the mid-1990s, based on the understanding of the nature and extent of contamination at that time. Since the interim remedies were implemented, additional characterization activities (i.e., the remedial investigations), along with information gained from continued operation of the remedial systems and expansion of well networks, have substantially increased the understanding of the nature and extent of Cr(VI) contamination in groundwater. Additional improvements have been made in interpretation of groundwater data, including enhanced contaminant plume interpolation processes and development of a method to evaluate the degree of river protection afforded by the remedial systems in place.

In 2006, based on *The Second CERCLA Five-Year Review Report for the Hanford Site*,[3] plans were initiated to expand the remedial systems to provide comprehensive treatment of the plumes in the aquifer. Expanded system capacity has been installed at all three OUs.

[3] DOE/RL-2006-20, 2006, *The Second CERCLA Five-Year Review Report for the Hanford Site*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04570094.

Expansion has included increased treatment capacity in the 100-HR-3 and 100-KR-4 OUs by constructing the DX, HX, and KX P&T systems; incorporating high-capacity ResinTech[4] SIR-700 ion-exchange resin into the treatment systems; and expanding groundwater extraction through the installation of new high-capacity extraction wells at selected locations and increasing extraction rates at existing locations.

Although the interim remedial actions are effective and have demonstrated improvement in both protecting the Columbia River and reducing groundwater contaminant concentrations, remedies are not yet complete. Interim remedial action operations will continue, along with monitoring activities and remedial process optimization. Monitoring and optimization activities include the following:

- Regularly evaluating the results of sampling and analysis for groundwater samples collected from wells, aquifer tubes, and treatment process locations.
- Regularly evaluating individual extraction and injection well performance.
- Regularly evaluating estimated hydraulic capture by remedial systems.
- Regularly evaluating treatment process performance.
- Adjusting P&T system operations to optimize system performance in response to observed conditions. System adjustments have included modifying the treatment plants in the 100-K Area to expand treatment capacity by reducing the number of resin vessels in each treatment train to use the high-capacity ResinTech SIR-700 ion-exchange resin more effectively.
- Future apatite chemical injections to complete the 100-N apatite PRB to a total planned length of 760 m (2,500 ft).

[4] ResinTech® is a registered trademark of RESINTECH INC., West Berlin, New Jersey.

Contents

Figures

Tables

This page intentionally left blank.

Terms

amsl	above mean sea level
AT	aquifer tube
AWLN	automated water-level network
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFM	capture frequency map
COC	contaminant of concern
Cr(VI)	hexavalent chromium
CSM	conceptual site model
CY	calendar year
DO	dissolved oxygen
DOE	U.S. Department of Energy
DWS	drinking water standard
Ecology	Washington State Department of Ecology
ESD	explanation of significant differences
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FSB	fuel storage basin
FY	fiscal year
IC	institutional control
ICFM	interpolated capture frequency map
ID	identification
ISRM	in situ redox manipulation
IX	ion exchange
LNAPL	light nonaqueous-phase liquid
MCL	maximum contaminant level
N/A	not applicable
NC	not calculated
NPL	National Priorities List

NR	not reported
NS	not sampled
NSD	not sufficient data
O&M	operations and maintenance
OU	operable unit
P&T	pump and treat
PLC	programmable logic controller
PRB	permeable reactive barrier
QA	quality assurance
QC	quality control
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
RD/RAWP	remedial design report/remedial action work plan
RI	remedial investigation
ROD	Record of Decision
RPO	remedial process optimization
RUM	Ringold upper mud unit
SAP	sampling and analysis plan
SCFM	simulated capture frequency map
TCE	trichloroethene
TPH	total petroleum hydrocarbon
TPH-D	TPH- diesel
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
UK	universal kriging
UPR	unplanned release
USGS	U.S. Geological Survey
WIDS	Waste Information Data System

1 Introduction

The U.S. Department of Energy (DOE) currently operates and maintains five ion-exchange (IX) pump and treat (P&T) systems along the Columbia River Corridor. In addition, DOE maintains one permeable reactive barrier (PRB), and monitors a second PRB as part of ongoing efforts to remediate contaminated groundwater in the Hanford Site's 100-KR-4, 100-HR-3, and 100-NR-2 Groundwater Operable Units (OUs) (Figure 1-1). The primary contaminant of concern (COC) in the 100-KR-4 and 100-HR-3 OUs is hexavalent chromium (Cr(VI)). The primary COC in the 100-NR-2 OU is strontium-90.

Two P&T systems (DX and HX) operated throughout 2015 to remediate Cr(VI) in the 100-HR-3 Groundwater OU, which includes the combined 100-D and 100-H Areas, and the Horn. These much larger P&T systems replaced the DR-5 and HR-3 P&T systems, which were shut down in March 2011 and May 2011, respectively. In addition, an in situ redox manipulation (ISRM) PRB was installed in the southwestern portion of the 100-D Area starting in 2000. This barrier continues to reduce Cr(VI) in groundwater, but is no longer maintained as an active remediation treatment. The remaining three P&T systems (KR4, KX, and KW) remediate Cr(VI) contamination within the 100-KR-4 Groundwater OU. Table 1-1 lists the design capacity and the number of extraction and injection wells that operated in 2015 for each of the five P&T systems. Additionally, Table 1-1 summarizes the average flow rate plus average influent and effluent Cr(VI) concentration, groundwater volume treated, and Cr(VI) mass removed in 2015 for each P&T system.

The interim actions conducted at the 100-HR-3 and 100-KR-4 OUs are part of the effort to achieve the following interim remedial action objectives (RAOs), as described in EPA/ROD/R10-96/134, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington*:

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- **RAO #2:** Protect human health by preventing exposure to contaminants in the groundwater.
- **RAO #3:** Provide information that will lead to a final remedy.

The interim remedial action initially chosen for the 100-NR-2 OU was P&T using an IX medium to remove strontium-90. The RAOs were reviewed in 2005, and the P&T system was deemed ineffective in reducing the strontium-90 flux to the Columbia River. In accordance with the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) Milestone M-16-06-01 ("PRB at 100-N"), the 100-NR-2 P&T system was placed in cold-standby status on March 9, 2006. DOE began installing a PRB along the 100-N Area shoreline in 2007 with the goal of sequestering strontium-90 in the aquifer (DOE/RL-2005-96, *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit*). The remedial technology implemented uses apatite as a reactive material to sequester strontium-90 from the groundwater.

The following four RAOs for the 100-NR-2 OU are described in the current interim Record of Decision (ROD) (EPA, 2010, *U.S. Department of Energy 100-NR-1 and NR-2 Operable Units Hanford Site - 100 Area Benton County, Washington Amended Record of Decision, Decision Summary and Responsiveness Summary*):

- **RAO #1:** Protect the Columbia River from adverse impacts from the 100-NR-2 groundwater so designated beneficial uses of the Columbia River are maintained.
- **RAO #2:** Protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants present in the unconfined aquifer.

- **RAO #3:** Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater.
- **RAO #4:** Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat in general and prevent adverse impacts to cultural resources and threatened or endangered species.

Tri-Party Agreement (Ecology et al., 1989) target date milestones have been established for remedial actions to protect the Columbia River and groundwater from further impact due to Cr(VI) and other contaminants resulting from Hanford Site operations. The following four target date milestones are directly applicable to the 100 Area OUs:

- ***Milestone M-016-110-T01 (December 31, 2012):*** *DOE shall take actions necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area National Priorities List (NPL) Operable Units such that ambient water quality standards for hexavalent chromium are achieved in the hyporheic zone and river column water.*

  DOE continues to optimize groundwater remedies in the 100 Areas. Groundwater P&T systems in the 100-HR-3 and 100-KR-4 OUs show continuing improvement in river protection. In 2015, the 100-D Area exhibited a 60 percent increase in protected shoreline length and 40 percent reduction in unprotected shoreline length. The 100-H Area exhibited a 15 percent increase in protected shoreline length and no net change in unprotected shoreline length. The 100-K Area exhibited a 20 percent increase in protected shoreline length and 50 percent reduction in unprotected shoreline length in 2015.

  Milestone M-016-110-T02 (December 31, 2020): *DOE shall take actions necessary to remediate hexavalent chromium groundwater plumes such that hexavalent chromium will meet drinking water standards in each of the 100 Area NPL Operable Units.*

  DOE's operation and enhancement of Cr(VI) groundwater remedies in the 100 Areas continued to reduce overall groundwater chromium concentrations. Plume areas exceeding drinking water standards have been substantially diminished in the 100-HR-3 and 100-KR-4 OUs.

- ***Milestone M-016-110-T03 (December 31, 2016):*** *DOE shall take actions to contain the strontium-90 plume at 100-NR-2 Operable Unit such that the default ambient water quality standard (8 pCi/L) is achieved in the hyporheic zone and river water column.*

  DOE has demonstrated the efficacy of a PRB to reduce strontium-90 releases to the river from contaminated groundwater at the 100-NR-2 OU. Plans are in place to expand the barrier treatment.

- ***Milestone M-016-110-T04 (December 31, 2016):*** *DOE shall implement remedial actions selected in all 100 Area Records of Decision for Groundwater Operable Units so that no contamination above drinking water standards enters the Columbia River unless otherwise specified in a CERCLA decision.*

  DOE will continue to address identified COCs in groundwater in the 100 Areas in RODs. Final remedial actions are not limited to Cr(VI); for example, groundwater in the 100-KR-4 OU also includes elevated concentrations of trichloroethene, strontium-90, carbon-14, tritium, and nitrate in addition to chromium.

Remedial actions toward achieving Tri-Party Agreement Milestone M-016-110-T01 have been implemented in the 100-HR-3 and 100-KR-4 OUs (12-AMRP-0172, "Completion of Hanford Facility Agreement and Consent Order (Tri-Party Agreement) Target Milestone M-016-110-T01 ("DOE Shall Take Actions Necessary to Contain or Remediate Hexavalent Chromium Groundwater Plumes in Each of the 100 Area National Priority List Operable Units Such that Ambient Water Quality Standards for

Hexavalent Chromium are Achieved in the Hyporheic Zone and River Water Column"). These remedial actions are not yet complete, but current estimates indicate that the P&T approach is capable of remediating the Cr(VI) contamination in the affected aquifer. Annual assessments of river protection status, which are presented in Chapter 2 for the 100-HR-3 OU and in Chapter 3 for the 100-KR-4 OU, indicate continuing improvement in river protection for these two OUs. DOE reviews remedial action progress regularly and annually evaluates recommendations for changes to the remedial action systems to improve system performance and shorten the time to remedy completion. Remedial investigations (RIs) and feasibility studies (FSs) currently being conducted for the 100 Area OUs address the other target date milestones. The status of the RI/FS activities for the specific OUs discussed in this report is presented in subsequent chapters.

Additional information on site history for the 100-HR-3, 100-KR-4, and 100-NR-2 OUs is provided in Appendix A of DOE/RL-2014-25, *Calendar Year 2013 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*. The appendix presents a chronology of the investigations and decisions for the interim remedial actions, and it summarizes the conceptual site models (CSMs) associated with groundwater contamination at the OUs.

This annual summary report discusses the groundwater remedial actions conducted during 2015 at the 100-HR-3 OU (Chapter 2), the 100-KR-4 OU (Chapter 3), and the 100-NR-2 OU (Chapter 4). A cost evaluation for each OU is presented in the respective chapters. The references cited in this report are included in Chapter 5.

1.1 100-HR-3 Operable Unit Activities

The following subsections provide a brief summary of the activities at the 100-HR-3 OU for the reporting period.

1.1.1 100-HR-3 Operable Unit Pump and Treat Systems

The DX and HX P&T systems operated throughout 2015, with several wells realigned to improve capture and remove mass from the aquifer. As presented in DOE/RL-2014-25, areas along the Columbia River were classified as "protected," "not protected," or "action may be required." Those areas considered at risk for impacts from contamination were evaluated, and actions were initiated to improve river protection in those areas.

The 2015 system modifications included connecting new extraction wells (199-D5-154 and 199-D5-159), converting monitoring well 199-D5-34 to an extraction well, and connecting new injection well 699-93-48C to the DX P&T system well network. Wells 199-D5-154 and 199-D5-159 were put into service as extraction wells in February and July 2015, respectively, to target high concentrations in the 100-D northern plume. Monitoring well 199-D5-34 had increasing concentrations of Cr(VI) and was converted to an extraction well in August 2015. As a result of extraction operations at the new extraction wells, the concentrations in downgradient wells have declined and capture has improved (see Section 2.2.6). Injection well 699-93-48C was installed for additional injection capacity for disposal of extraction water. The well went into service in late August and operates at an average rate of 287 L/min (76 gal/min).

Modifications to the DX and HX P&T facilities included reconfiguring the IX treatment trains to a "split-train" configuration. Ongoing remediation has sufficiently reduced the maximum Cr(VI) concentrations in groundwater at the 100-D Area so that a two-vessel treatment train using high-efficiency ResinTech®[1] SIR-700 IX resin effectively removes the Cr(VI) contamination from the

[1] ResinTech is a registered trademark of RESINTECH INC., West Berlin, New Jersey.

treatment train influent. This approach effectively doubles the treatment capacity available in each treatment train by operating the original four-vessel treatment train in two parallel flow two-vessel treatment trains.

Multiple well realignments and system additions were made during 2015 to the HX P&T system. Realignment included turning off several extraction and injection wells within the reactor area and converting wells from injection to extraction or from extraction to injection, depending on the location. Details of the well realignments and system changes are described in Section 2.2.2.1. Figure 1-2 shows the current 100-HR-3 P&T system layout, and Figure 1-3 highlights the well changes to the P&T system configuration for 2014 and 2015. Modifications made to the P&T systems have improved capture along the river, although capture is not complete at the 100-D northern plume or along the southern boundary of the 100-D Area. Section 2.2 discusses these changes in detail.

Figures 1-4 and 1-5 show the annual and cumulative trends for groundwater volume treated and COC mass removed, respectively, from the 100-HR-3 P&T systems. In 2015, the 100-HR-3 P&T systems treated approximately 2,605 million L (688 million gal) and removed 109.6 kg (241 lb) of Cr(VI) from the groundwater. This is a 46 percent reduction in mass removal from 2014, due primarily to the large decrease in Cr(VI) concentrations in the 100-D southern plume area near the 100-D-100 waste site, which is a result of ongoing extraction by the DX P&T system and source area remediation.

1.1.2 In Situ Redox Manipulation

In 2000, additional cleanup action was taken using an in situ chemical treatment technology (i.e., ISRM). Use of this new technology was approved by the 1999 interim ROD amendment (EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*). Rather than pumping contaminated groundwater to the surface for treatment, this technology treats the groundwater in the aquifer by reducing Cr(VI) to trivalent chromium, which is a much less toxic and less mobile form. Due to breakthrough of contaminants at the ISRM barrier, a notice of non-significant change to the ROD was issued in 2010, which indicated that the barrier would no longer be actively maintained (11-AMCP-0002, "Non-Significant Change for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision, Hanford Site, Washington, July 2010, Memo to File Regarding: Supplemental Actions for the In-Situ Reduction/Oxidation Manipulation Barrier Performance for the 100-HR-3 Groundwater Operable Unit Interim Remedy"). The notice of non-significance shifted the groundwater remedy at the ISRM barrier to the P&T system.

The ISRM barrier is still monitored for effectiveness and continued to convert Cr(VI) to a nontoxic, immobile form (trivalent chromium) within a portion of the aquifer in 2015. Concentrations in some downgradient wells remained above the ambient water quality criteria and interim remedial action target of 10 μg/L and 20 μg/L, respectively, since the northeast segment of the barrier does not work effectively. Groundwater in this area is captured by extraction wells installed for the DX P&T system. Sections 2.1.2 and 2.2.8 discuss the ISRM treatment technology and its effectiveness in detail.

1.1.3 Remedial Investigation/Feasibility Study Activities

An RI/FS is being conducted for the 100-D and 100-H Areas and the Horn. Characterization activities began in 2009, as described in DOE/RL-2008-46-ADD1, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*; and implemented through DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*. The RI/FS addresses contaminant sources (e.g., site history), contaminant flow and transport, and exposure assessment. It also supports risk characterization, remedial action selection, performance monitoring, and site closure. DOE completed Rev. 0 of the RI/FS report

(DOE/RL-2010-95, *Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*) in October 2014. The RI/FS results support selection of final remedies under CERCLA, using an approach that integrates source and groundwater remedial actions, which is documented in the draft Proposed Plan (DOE/RL-2011-111, *Proposed Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*). The Washington State Department of Ecology (Ecology) is currently reviewing the Proposed Plan, which will lead to a ROD for cleanup of contaminated soil and groundwater at the 100-D and 100-H Areas. The Proposed Plan is expected to be available for public comment in 2016. After public comments are received and addressed, a ROD will be issued that identifies the final remedial alternatives.

Of particular interest to understanding the CSM for Cr(VI) in groundwater at the 100-HR-3 OU, and specifically within the 100-D Area, is the waste site remediation and subsequent aquifer characterization conducted at the 100-D-100 waste site during 2014. During early 2014, excavation of chromium-contaminated vadose zone soil was completed at the 100-D-100 and 100-D-30/104 waste sites. Conditions at both of these sites exhibited full-thickness vadose zone contamination by Cr(VI). The chromium entered the vadose zone from historical unplanned releases of high-concentration sodium dichromate dihydrate solution. These releases were of sufficient volume to cause the chromium solution to travel through the entire vadose zone thickness and enter the underlying unconfined aquifer. Additional investigation efforts during 2014 indicated that residual Cr(VI) within the vadose zone, as well as within the aquifer, was present as a chromate-substituted calcite. This material is sparingly soluble in water and forms a persistent secondary source of groundwater contamination where it occurs in substantial quantities, as it did within the soil and aquifer volume underlying these waste sites (SGW-58416, *Persistent Source Investigation at 100-D Area*).

A series of temporary groundwater monitoring wells was installed within the aquifer underlying the 100-D-100 waste site. Vertical profile soil/aquifer media samples were collected when these wells were drilled, and moderate-frequency (i.e., weekly to monthly) groundwater samples were collected from the wells to provide additional understanding of the secondary source contribution of these solid-phase minerals. The chromate-substituted calcite was found to present a persistent groundwater contamination source. As a result, additional removal of contaminated soil was initiated in November 2014 and completed in February 2015, to remove contamination in the aquifer sediments to a depth of 3 m (10 ft) below the water table at the 100-D-100 waste site.

Based on the observations and measurements of the secondary vadose zone source at the 100-D Area, there is potential that similar secondary source material within the vadose zone and aquifer material exists at other locations where high-concentration sodium dichromate dihydrate solution was released to the ground. The potential source areas include the 183-KE and 183-KW Head House areas in the 100-KR-4 OU. Active groundwater interim action remediation continued during 2015, in conjunction with preparing RI/FS reports that will support RODs for future implementation of final remedies.

1.2 100-KR-4 Operable Unit Activities

The following subsections provide a brief summary of activities at the 100-KR-4 OU for the reporting period.

1.2.1 100-KR-4 Operable Unit Pump and Treat Systems

Three active systems continued operating in the 100-KR-4 OU during 2015. The KR4 P&T system treats groundwater downgradient from the 116-K-2 Trench, with a treatment capacity of 1,136 L/min (300 gal/min). The KX P&T system treats groundwater between the 116-K-2 Trench and the N Reactor area, as well as a plume downgradient of the KE Reactor. The KX P&T system has a 2,300 L/min (600 gal/min) design treatment capacity. The KW P&T system extracts groundwater around the

KW Reactor facility and has a treatment capacity of 1,136 L/min (300 gal/min). Figure 1-6 shows the layout of the 100-KR-4 OU P&T systems.

Figure 1-7 highlights the changes to the 100-KR-4 OU P&T system configuration implemented from 2013 through 2015. Well realignments for the 100-KR-4 OU P&T systems in 2013 and 14 included the addition of two new extraction wells (199-K-198 and 199-K-199) to the KR4 P&T system to improve capture near the river shoreline. One new extraction well (199-K-205, located at the 183-KW Head House area) and one new injection well (199-K-206, located between injection Wells 199-K-158 and 199-K-175) were constructed and connected to the KW P&T system. These wells allowed increased water treatment rate at the KW P&T system, as well as providing high-capacity extraction at the head house vicinity.

Three new extractions wells were connected to the KX P&T system in 2014. Extraction wells 199-K-210 and 199-K-212 were added to improve river protection by enhancing capture of the Cr(VI) plume in the near-river vicinity downgradient of the KE Reactor (199-K-210), and along the 116-K-2 Trench (199-K-212). Extraction well 199-K-220 was installed near the 183-KE Head House to provide mass removal from that source area. KX P&T system modifications included loading the third and fourth vessels in the treatment trains with ResinTech IX SIR-700 resin to provide additional treatment capacity. This increased capacity was demonstrated during 2014 when the KX P&T system was operated at a maximum daily throughput rate of 2,926.1 L/min (773 gal/min). One new extraction well (199-K-208) was connected to the KX P&T system in 2015 to improve river protection by enhancing capture of the Cr(VI) plume in the near-river area downgradient of the KE Reactor, as well as to improve mass removal. Section 3.1 provides a detailed discussion of these changes.

During 2015, the combined systems treated 2,894 million L (764 million gal) and removed 50.1 kg (110 lb) of Cr(VI). Figures 1-8 and 1-9 show the annual and cumulative trends for volume treated and mass removed, respectively, from the 100-KR-4 OU P&T systems. The groundwater treatment systems at the 100-KR-4 OU are presently operating in a "split-train" configuration. With the implementation of high-efficiency, high-capacity SIR-700 IX resin, the systems were found to function effectively using a two-vessel treatment train, which allows the remaining two vessels of the original four-vessel train to be used for additional plant treatment capacity. Using this approach, the capacity of the KR4 and KW P&T systems has been effectively doubled. The KX P&T system is also running on the two-vessel train configuration; the third and fourth vessels in each treatment train at KX were loaded with SIR-700 resin during 2014 to prepare for operating the KX P&T system in full split-train mode.

1.2.2 Remedial Process Optimization Activities

Remedial process optimization (RPO) activities at the 100-KR-4 OU remedial systems have evolved over recent years and currently focus on the following system aspects:

- **Assessing extraction and injection well performance:** This includes evaluation of individual well performance and the identification of wells that need maintenance. This also includes evaluating individual pumping rates for extraction wells located within specific portions of contaminant plumes (e.g., at or near source areas, along the leading edge of plumes).

- **Evaluating well network performance:** This includes evaluating the placement and pumping rates of wells with respect to the inferred contaminant plume distribution. Modeling tools are used to evaluate anticipated well field performance under selected pumping scenarios. Based on these assessments, additional extraction capability has been added to the 100-K remedial systems by realigning selected existing wells as extraction wells and by drilling and constructing new wells, focusing on enhancing contaminant capture and mass removal in source areas (e.g., the 183-KE and 183-KW Head House areas) and river protection by enhancing capture along the leading edges of plumes that approach or intersect the river.

- **Assessing treatment process effectiveness:** This evaluation led to the changeover in 2011 to the current SIR-700 IX resin. This resin has continued to provide highly efficient removal of Cr(VI) from extracted groundwater. No resin changes have been required at any of the three 100-K Area treatment systems since the use of SIR-700 resin was initiated. An evaluation is under way to assess the potential need for, and alternative approaches to, management of pH of the treatment process effluent water in the 100-K Area P&T systems. The KR4, KW, and KX treatment systems are presently not configured for alkaline adjustment of the treated water effluent.

1.3 100-NR-2 Operable Unit Activities

The following subsections provide a brief summary of activities at the 100-NR-2 OU for the reporting period.

1.3.1 100-NR-2 Operable Unit Pump and Treat System

The 100-NR-2 P&T system was placed in cold-standby status in March 2006. Contaminant concentrations have been tracked in previous reports (e.g., DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*) to quantify the effect on groundwater and the recovery of the water table to pre-pumping conditions.

1.3.2 100-NR-2 Operable Unit Permeable Reactive Barrier

Under the existing interim action ROD (EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*) and Tri-Party Agreement (Ecology et al., 1989) Change Control Form M-16-06-01 dated February 15, 2006, DOE agreed to construct and evaluate the effectiveness of a PRB for strontium-90 using apatite sequestration technology as part of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) RI/FS process. Change request M-16-06-01 established two new milestones [M-016-14(a) and M-016-14(b)] for the construction and evaluation of a 300-foot permeable reactive barrier utilizing apatite sequestration at 100-N. Milestones M-016-14(a) and M-016-14(b) were completed in 2007 (as documented by 07-AMCP-0266, *Completion of Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Milestone M-16-14A, "Complete Construction of a Permeable Reactive Barrier at 100-N" and Completion of Calendar Year 2007 Construction Activities at the 100-N Sequestration Barrier*) and 2009 (as documented by 10-AMCP-0032, *Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision, DOE/RL-2009-54, Draft B*), respectively.

No additional injections were conducted in 2015. Wells and aquifer tubes downgradient of the treated segments of the PRB continued to be monitored. Treated segments of the PRB include the following:

- From 2006 through 2008, DOE installed the first apatite PRB along 91 m (300 ft) of the most contaminated section of 100-N Area shoreline. Since 2008, this section of the shoreline has been monitored to track the formation of apatite within the vadose zone and groundwater and to determine the effectiveness of the PRB in attenuating strontium-90 and reducing its release to the Columbia River. The PRB has shown a 90 percent reduction of strontium-90 concentrations at the river's edge (PNNL-19572, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization, Final Report*). In response to the success of the existing PRB, DOE installed 146 new injection wells and 25 new monitoring wells along the remainder of the 100-N Area shoreline in 2009 and 2010, to enable future expansion upriver and downriver of the existing PRB to a total length of 760 m (2,500 ft).

- Wells in two 110 m (360 ft) long PRB segments (one upriver and one downriver of the original 91 m [300 ft] long segment) were injected with apatite solutions in 2011 (DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*), which expanded the original barrier upstream and downstream and increased the current treated portion of the 100-N Area shoreline to 270 m (900 ft) in length. The injections were performed using a two-step process, where the deeper Ringold Formation wells were injected first and then the overlying Hanford formation wells were injected. These staggered injections overlay each other and maximize the coverage in the upper unconfined aquifer and lower vadose zones. The formulation for these injections was the high-concentration, calcium-citrate-phosphate solution amendment that was tested in 2008 (PNNL-19572). Groundwater monitoring of the upriver and downriver PRB extension indicate the concentrations in the majority of the monitoring wells in 2015 were lower than preinjection levels by nearly 90 percent. However, in 2015 concentrations of strontium-90 have increased in some of the monitoring wells, and are close to preinjection levels in two monitoring wells. Further discussion on PRB performance is presented in Chapter 4.

Figure 1-10 shows the location of the original PRB and the upstream and downstream extensions. Performance monitoring is ongoing along the entire treated portion of the barrier and is discussed further in Chapter 4. Future PRB expansion will increase the barrier along the entire length of the contaminated portion of the 100-N Area shoreline by approximately 760 m (2,500 ft).

1.4 Quality Assurance/Quality Control

Discussions on quality assurance (QA) and quality control (QC) encompassing sampling and analysis of the wells are provided in Appendix F of DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*. It includes an overall view of the QA/QC issues that may affect interpretation of the groundwater data.

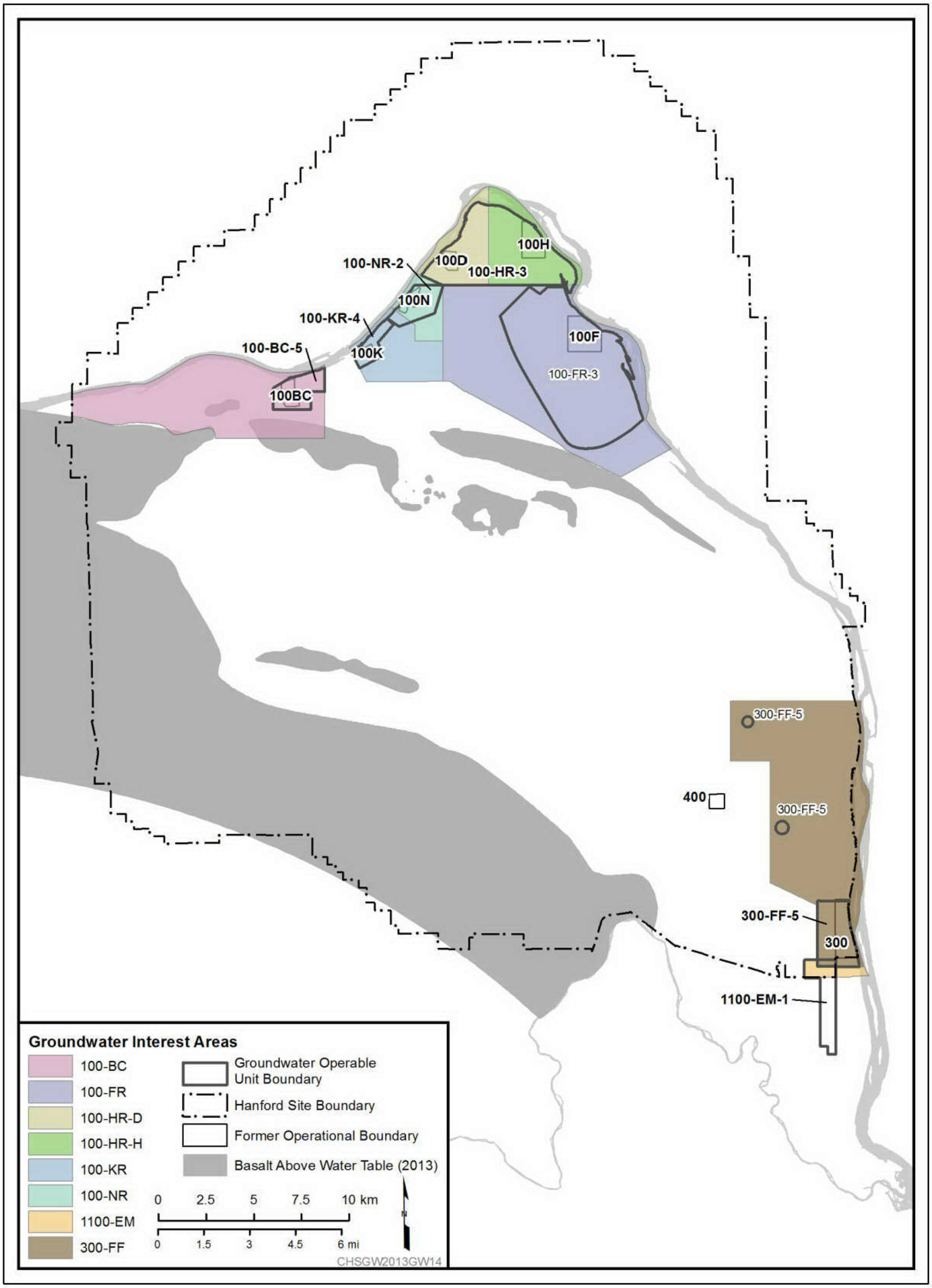


Figure 1-1. Locations of Groundwater OUs and Interest Areas along the Columbia River

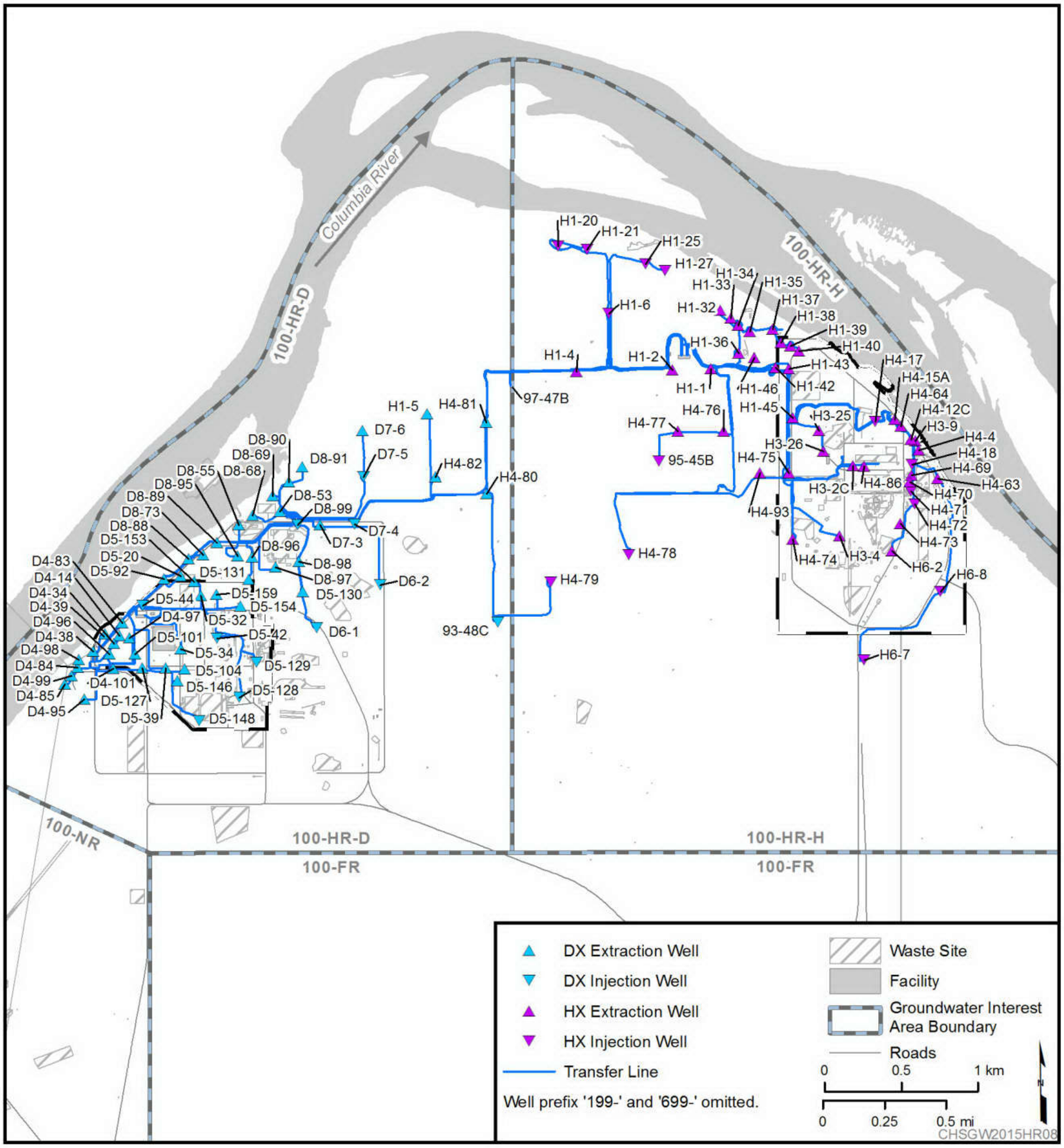


Figure 1-2. Layout of the 100-HR-3 OU P&T Systems (as of December 31, 2015)

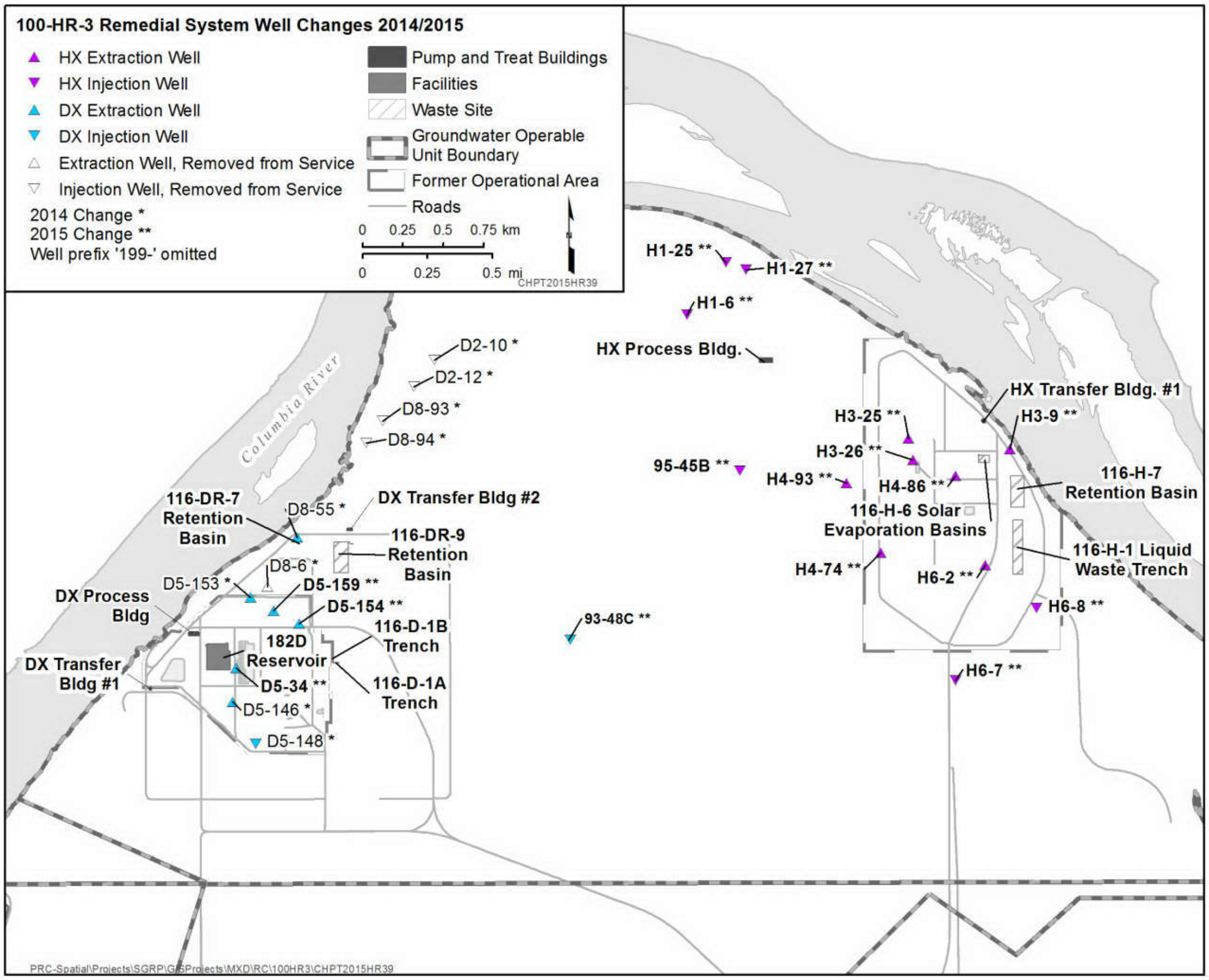


Figure 1-3. Well Changes to the 100-HR-3 OU P&T Systems in 2015

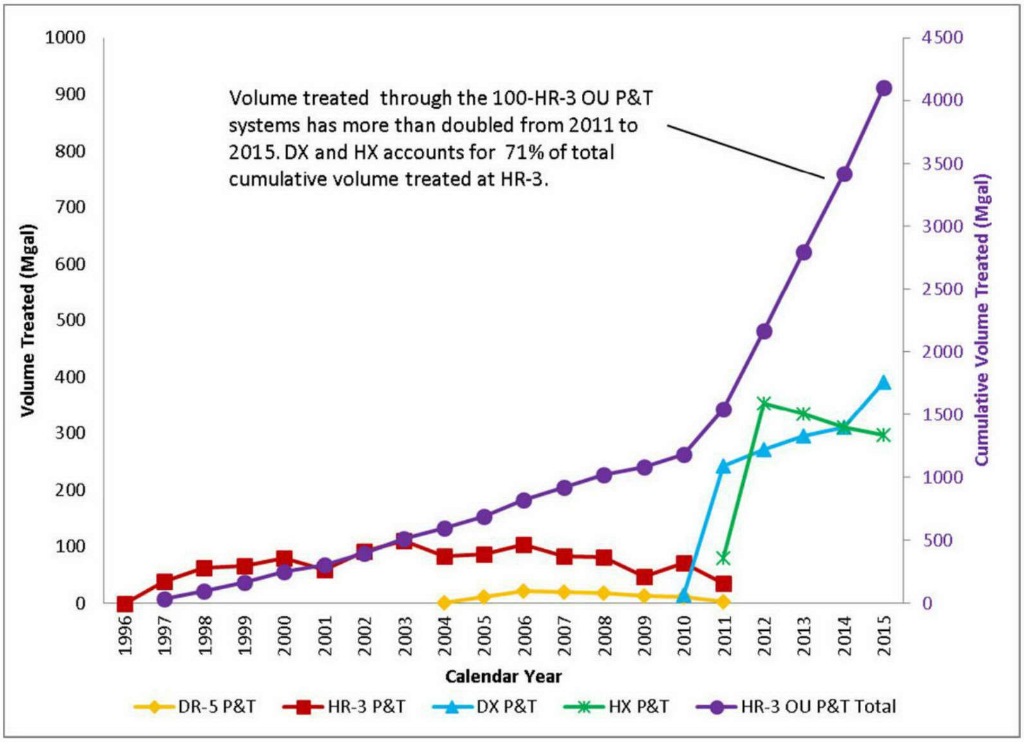


Figure 1-4. Volume Treated at the 100-HR-3 OU P&T Systems

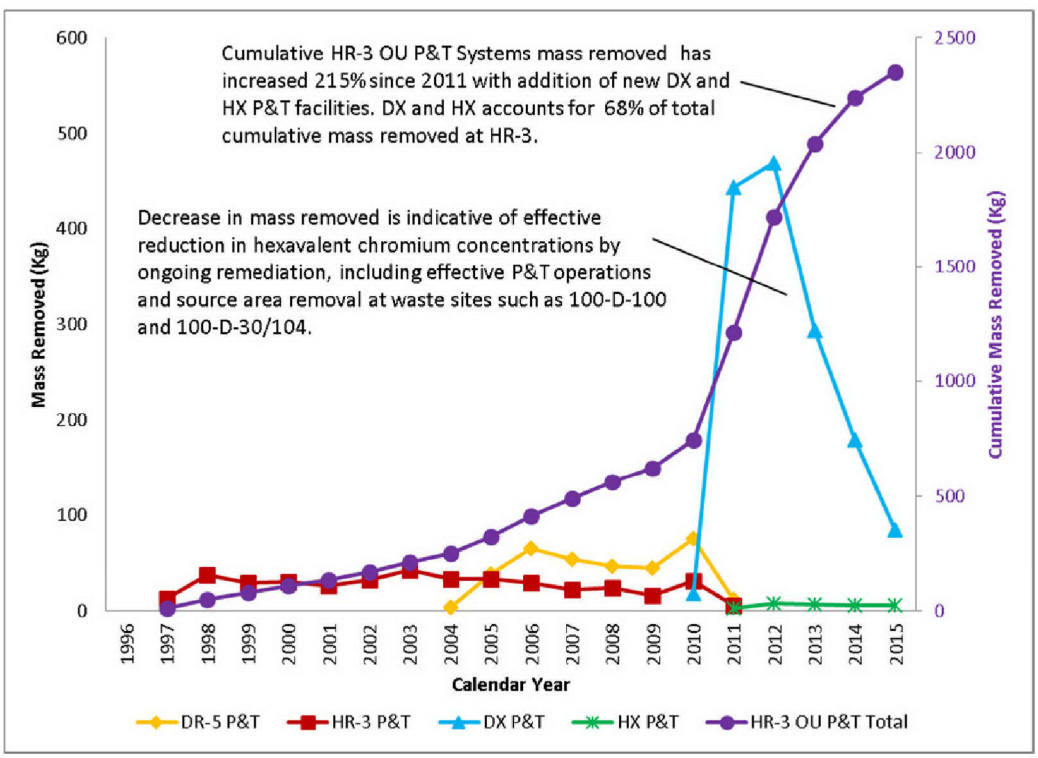
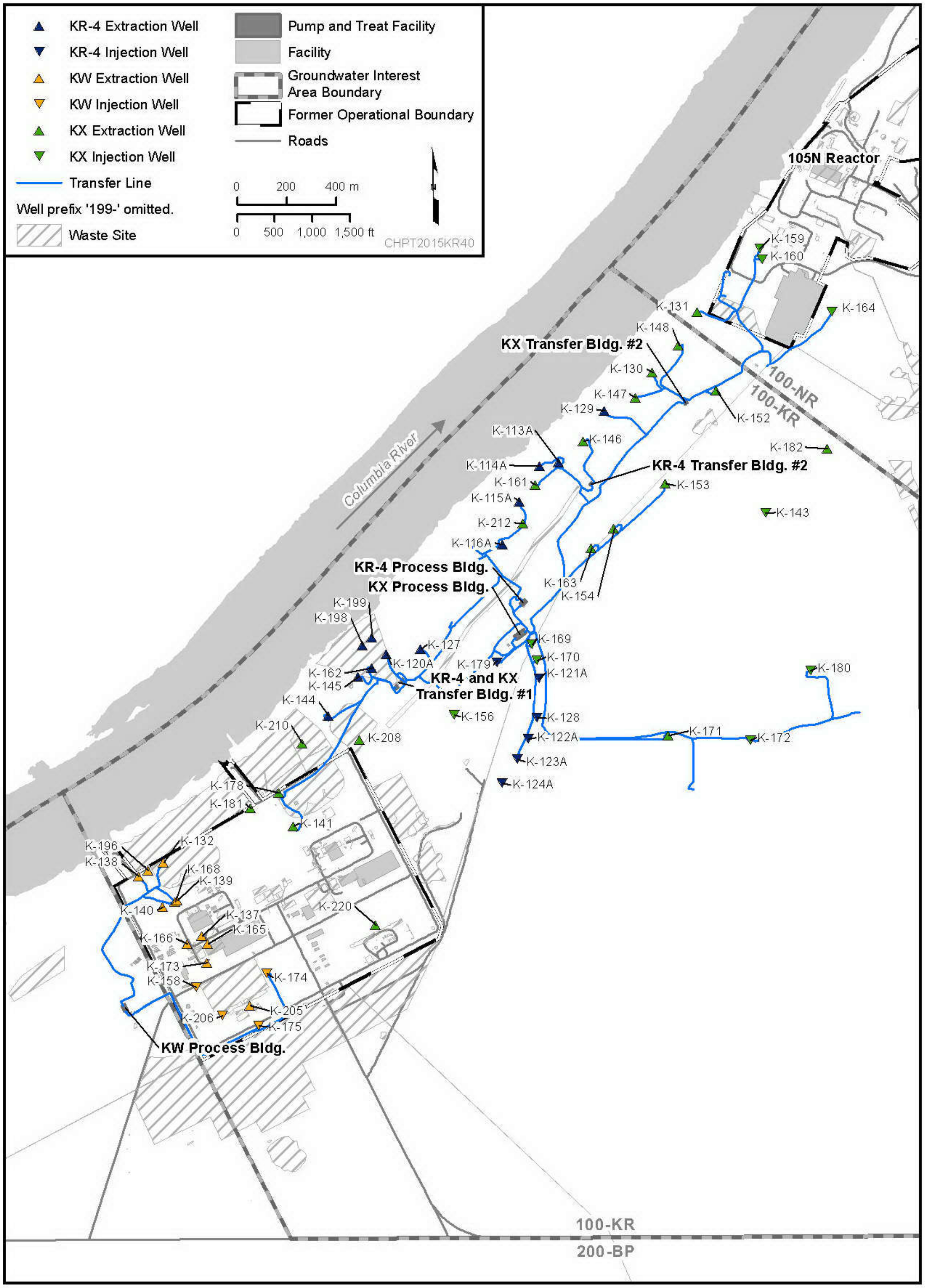
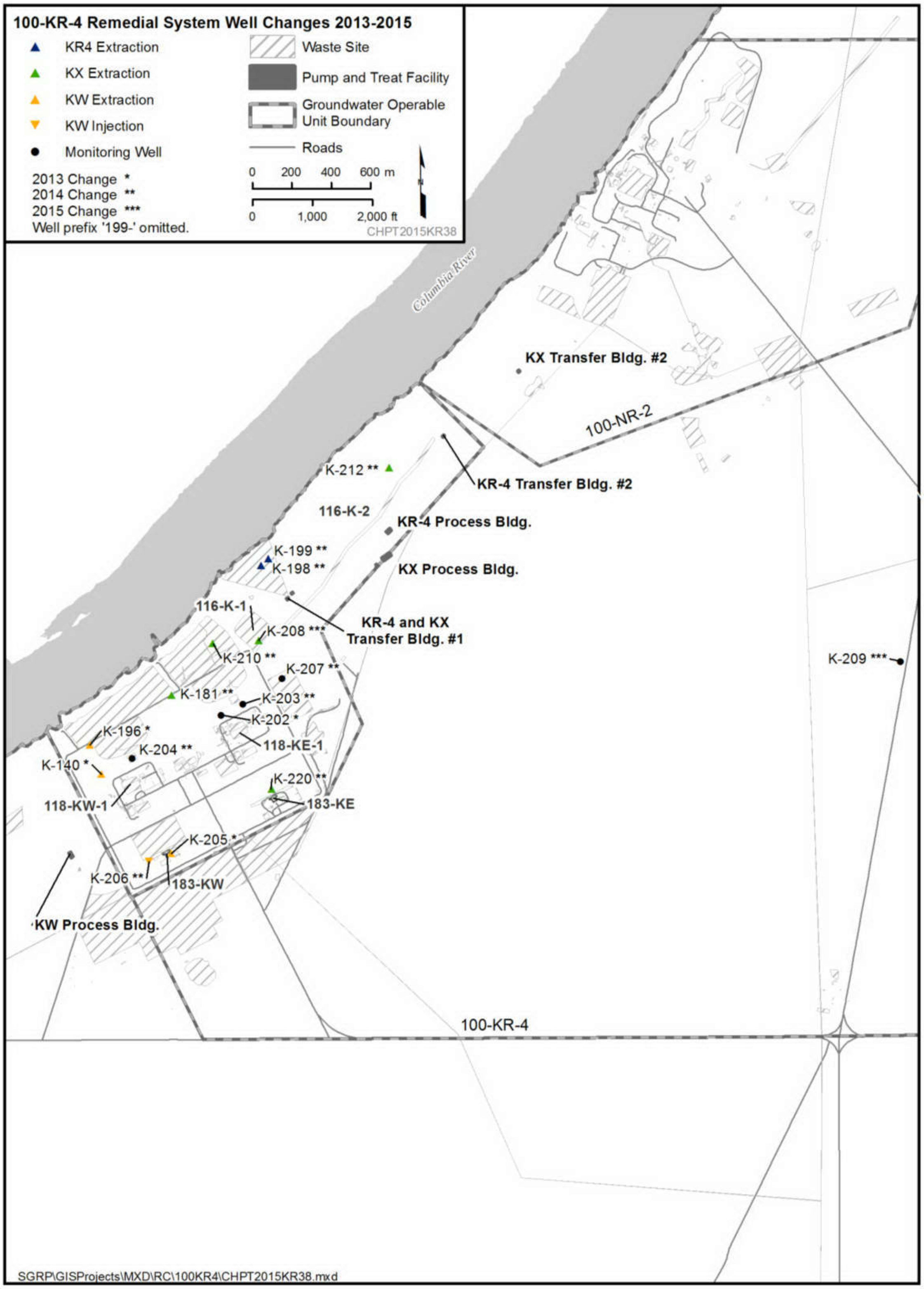


Figure 1-5. Cr(VI) Mass Removed by the 100-HR-3 OU P&T Systems



1

2 Figure 1-6. Layout of the 100-KR-4 OU P&T Systems

1 

2 **Figure 1-7. Extraction, Injection, and Monitoring Wells Added to the 100-KR-4 OU Well Network in 2015**

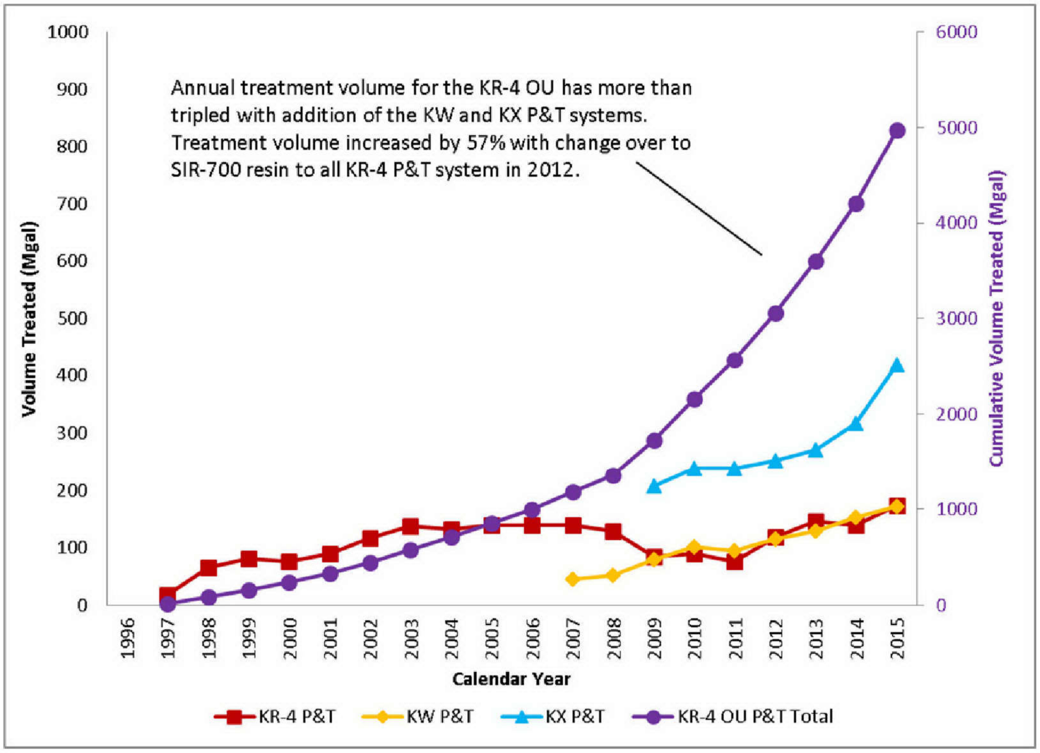


Figure 1-8. Volume Treated at the 100-KR-4 OU P&T Systems

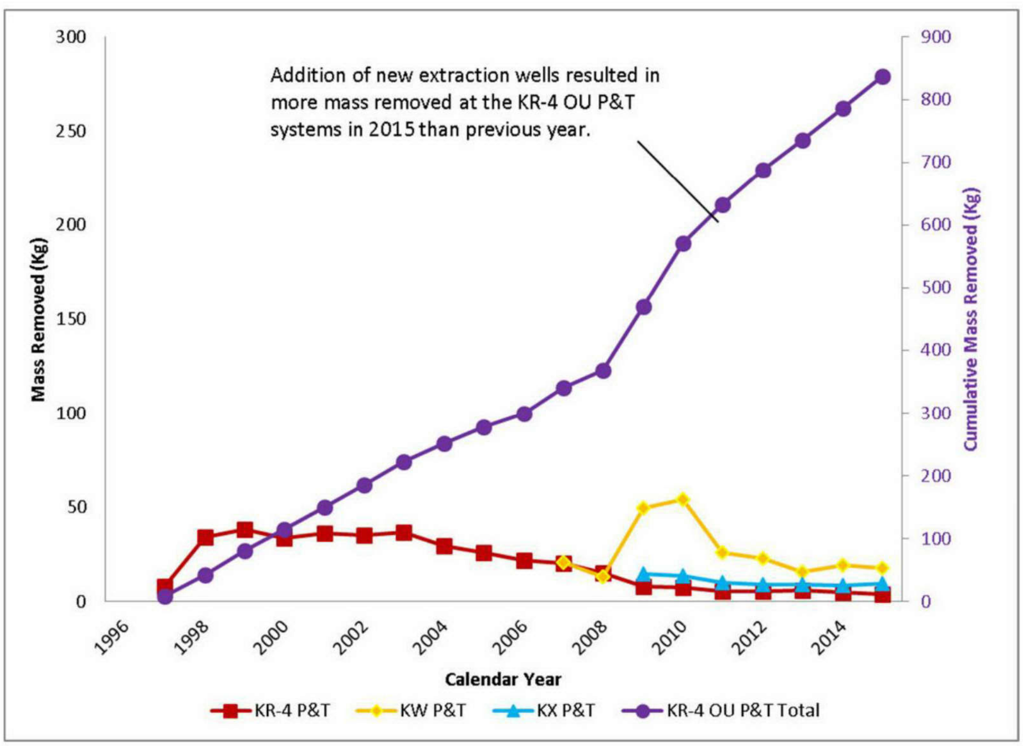


Figure 1-9. Cr(VI) Mass Removed by the 100-KR-4 OU P&T Systems

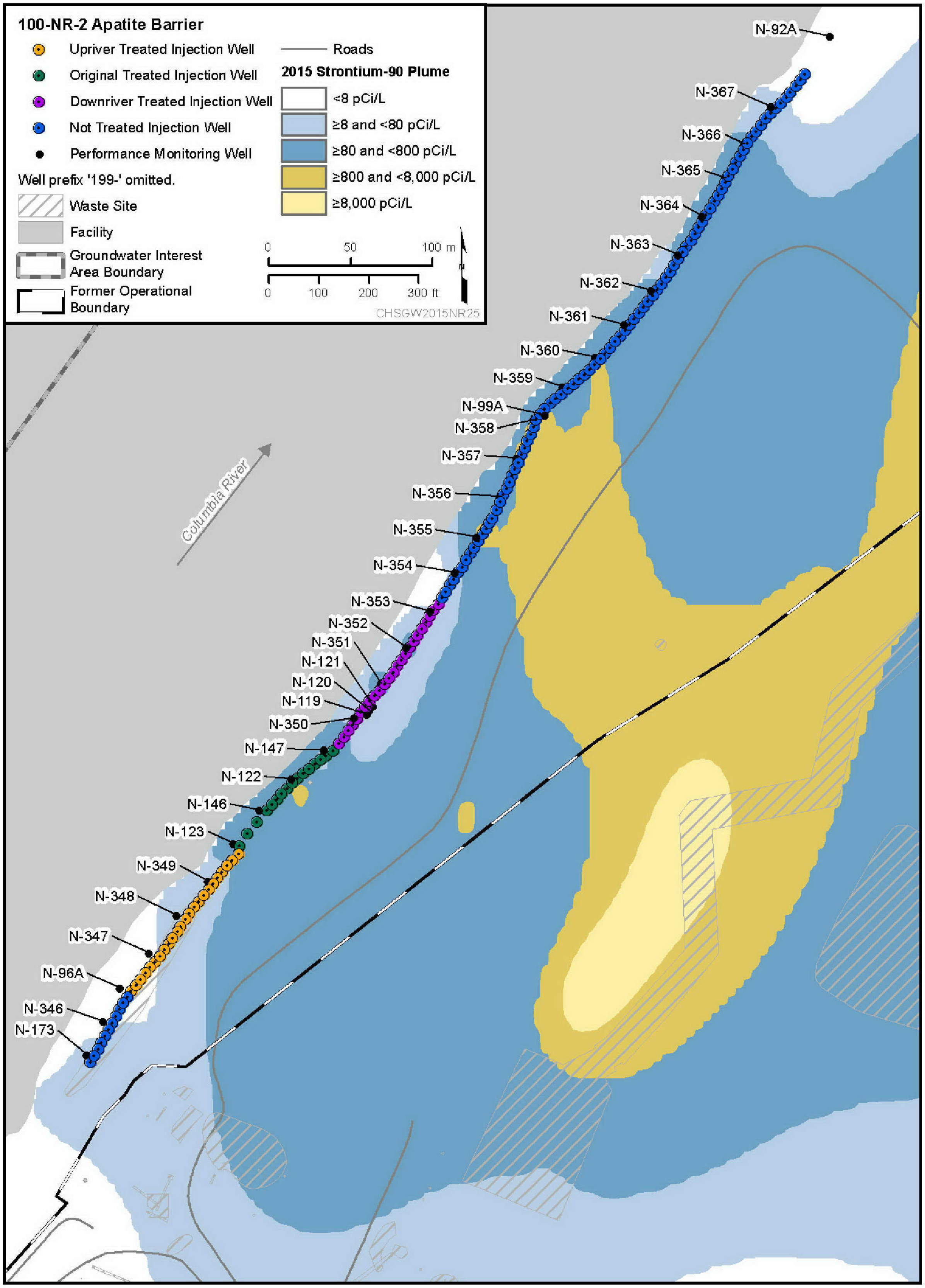


Figure 1-10. Treated Segments of the 100-NR-2 OU Apatite PRB

Table 1-1. 2015 P&T Performance Summary

Groundwater Operable Unit	100-HR-3		100-KR-4		
Pump and Treat System	**DX**	**HX**	**KW**	**KR4**	**KX**
Design capacity (L/min [gal/min])	2,273 (600)	3,030 (800)	758 (200)	1,136 (300)	2,273 (600)
Extraction wells (post-realignment)*	46	34	11	12	19
Injection wells (post-realignment)*	11	16	4	6	9
Average flow rate (L/min [gal/min])	2,818 (744)	2,138 (564)	1,239 (327)	1,249 (329)	3,038 (803)
Volume treated (million L [million gal])	1,482 (391)	1,123 (296)	651 (172)	655 (173)	1,586 (419)
Cr(VI) mass removed (kg)	84.6	24.9	17.6	4.0	28.6
Average Cr(VI) influent concentration (µg/L)	53.3	23.3	22.0	6.4	18.7
Average Cr(VI) effluent concentration (µg/L)	<2	<2	<2	<2	<2

* The number of extraction and injection wells does not include those that are not operational.

Cr(VI) = hexavalent chromium

This page intentionally left blank.

2 100-HR-3 Operable Unit Remediation

This chapter describes the status of the interim remedies and other CERCLA activities for the 100-HR-3 Groundwater OU. The following discussion includes the interim remedy P&T system performance and ISRM barrier monitoring.

2.1 Summary of Operable Unit Activities

The 100-HR-3 OU consists of the groundwater contaminated by releases from facilities and waste sites associated with past operation of the D, DR, and H Reactors that underlie the 100-D Area, the 100-H Area, and the region between known as the Horn (Figure 2-1). The Cr(VI) released from facilities and waste sites poses a risk to human health and/or the environment and is the primary COC identified in the interim action ROD (EPA/ROD/R10-96/134) for groundwater in the 100-HR-3 OU. Groundwater co-contaminants identified in this interim remedial action scope are nitrate, strontium-90, tritium, uranium, and technetium-99. Chromium (filtered), uranium, nitrate, fluoride, and technetium-99 are currently monitored as part of the *Resource Conservation and Recovery Act of 1976* (RCRA) permit for the 183-H Solar Evaporation Basins.

The interim remedial action ROD (EPA/ROD/R10-96/134) for the 100-HR-3 OU defined the cleanup goal for Cr(VI) in groundwater discharging to the Columbia River as the current ambient water quality criterion of 11 µg/L. Based in part on the expectation that contaminated groundwater (prior to discharging to the river) is mixed on a 1:1 basis with relatively uncontaminated water within a near-shore mixing zone along the river, attaining less than 22 µg/L of Cr(VI) in the compliance monitoring well network is consistent with achieving this RAO. The explanation of significant differences (ESD) for the 100-HR-3 and 100-KR-4 OUs (EPA et al., 2009, *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site, Benton County, Washington*) reduced the groundwater remediation target to 20 µg/L to meet the revised surface water quality criterion of 10 µg/L. Consequently, a compliance criterion of 20 µg/L for Cr(VI) in groundwater is currently applied to near-shore and compliance wells along the river. The drinking water standard (DWS) for total chromium remains at 100 µg/L. Ecology has established a Method B groundwater cleanup level of 48 µg/L for Cr(VI) under WAC 173-340, "Model Toxics Control Act—Cleanup."

To mitigate the risks associated with Cr(VI) contamination in groundwater discharging to the river, DOE initially installed a CERCLA interim action P&T system in the 100-HR-3 OU in 1997. The P&T interim remedial actions were implemented under DOE/RL-96-84, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, in accordance with the interim ROD (EPA/ROD/R10-96/134). A second P&T system, DR-5, was installed in 2004. In 2010, the two original systems were replaced with the larger DX and HX P&T systems, and both are currently operating. In addition, an ISRM barrier was installed in the southern portion of the 100-D Area starting in 2000. Due to breakthrough of contaminants at the ISRM barrier, a notice of non-significant change to the ROD was issued in 2010, which indicated that the barrier would no longer be actively maintained (11-AMCP-0002). The notice of non-significance change shifted the groundwater remedy at the ISRM barrier to the P&T system but maintained monitoring of the ISRM. The active interim action remedy in the 100-HR-3 OU is P&T and consists of the DX and HX P&T systems. The intent of the current interim remedial actions is to meet the RAOs described in Chapter 1.

Monitoring, data evaluation, and site characterization activities are conducted each year in an ongoing effort to determine the 100-HR-3 OU P&T systems' performance compared to design criteria, whether system design modifications or operating parameters will further optimize performance, and the measurable progress toward achieving plume cleanup and river protection RAOs. This chapter discusses the results of the 2015 100-HR-3 OU P&T evaluation and includes the following:

- Section 2.2 discusses the interim action groundwater-remediation activities, including the condition of ISRM.
- Section 2.3 provides the remedial action cost summary.
- Sections 2.4 and 2.5 include the conclusions and recommendations, respectively, for the 100-HR-3 OU.

2.1.1 100-HR-3 Operable Unit Pump and Treat Systems

This subsection describes the general operating status and notable modifications to the 100-HR-3 OU interim action P&T systems during 2015.

Changes to remedial systems during 2015 consisted of constructing additional wells for extraction and injection, realigning existing injection wells to extraction, and extraction wells to injection use, and changing the flow rates to select wells. These actions were intended to enhance hydraulic plume capture, reduce Cr(VI) plume concentrations, and remove mass from source areas. Twelve new wells were drilled in 2015, seven of which were connected to the P&T systems at 100-HR-3. The remaining wells are planned for connection to the P&T systems in 2016. In addition, there were 10 well realignments in the OU. Changes to the remedial systems are shown in Table 2-1. The locations of the new and realigned wells in 2015 are shown in Chapter 1, Figure 1-3.

Figures 2-2, 2-3, and 2-4 present the 2015 extraction, injection, and monitoring well locations for the 100-D Area, the ISRM portion of 100-D, and the 100-H Area, respectively. Figure 2-5 shows the well and aquifer tube locations in the Horn. The layouts of the P&T systems are shown in Figure 2-6.

2.1.2 In Situ Redox Manipulation Barrier

Prior to installation of the DX P&T system, additional cleanup action was deemed necessary in the southern portion of the 100-D Area. As approved by the 1999 interim ROD amendment (EPA/AMD/R10-00/122), an in situ chemical treatment technology was applied in 2000. The ISRM barrier (Figure 2-3) was installed to treat groundwater in the aquifer by reducing Cr(VI) to trivalent chromium, which is a much less toxic and less mobile form. However, due to breakthrough of contaminants at the ISRM barrier, Ecology issued a notice of non-significant change to the ROD in 2010, which indicated that the barrier would no longer be actively maintained (11-AMCP-0002). The notice of non-significance change shifted the groundwater remedy at the ISRM barrier to the P&T system. Groundwater at the ISRM site is still monitored for Cr(VI) and dissolved oxygen (DO) as part of CERCLA interim action monitoring, with Cr(VI) as the target contaminant. The DO levels are monitored along the barrier since the treatment process reduces oxygen content in the aquifer.

The DO levels along most of the ISRM barrier have returned to normal or nearly normal levels, with most wells indicating DO greater than 6 mg/L. An area of lower DO levels is present within the barrier, between wells 199-D4-19 and 199-D4-13, and at small area around well 199-D4-26 (Figure 2-7). The area within the barrier where DO levels remain low coincides with where groundwater velocity is slower and the aquifer is thinner due to a high in the Ringold upper mud (RUM) surface. The oxygen levels on the downgradient side of the barrier are at normal levels. A second area of lower DO levels is located near the former treatability test wells (199-D5-107 and 199-D5-108). The low DO in this second area does not extend much beyond the two test areas, which are limited to the two clusters of wells as described in PNNL-18784 (*Hanford 100-D Area Biostimulation Treatability Test Results*). Overall, the area of low DO levels is smaller than in previous years, indicating reduced barrier performance, as expected.

The Cr(VI) concentrations in barrier wells in 2015 ranged from below detection limits to 101 µg/L at well 199-D4-22. This well also had the highest concentration in the barrier during 2014, at 160 µg/L. The Cr(VI) concentration in groundwater flowing across the ISRM barrier trended downward throughout the year in most locations. In well 199-D4-25, however, concentrations increased from 22 µg/L in September to 60 µg/L in December 2015. Increased concentrations were also noted in monitoring wells 199-D4-62 and 199-D4-13, and in downgradient extraction well 199-D4-85. This localized increase indicates an area of reduced barrier performance and generally correlates with increasing DO levels. The overall declining Cr(VI) concentrations are attributed to the ongoing P&T system operations and the upgradient removal of source material, especially at waste site 100-D-100 where large volumes of highly contaminated soil were removed from both the vadose zone and the upper aquifer.

2.2 100-HR-3 Operable Unit Interim Action Activities

This section discusses the CERCLA activities for the 100-HR-3 OU during the reporting period, including activities related to operation and performance monitoring of the DX and HX P&T systems during 2015. Specific activities and operational performance details for these systems include system configuration changes and availability, contaminant mass removed during operation, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, and waste generation.

2.2.1 DX Pump and Treat System

The DX P&T system (Figure 2-8) was designed to capture and treat the Cr(VI) plume located in the 100-D Area, which is typically discussed as the 100-D "northern" and "southern" plumes. Releases of highly concentrated stock solution of sodium dichromate to the environment through spills, washout of vehicles and containers, and leaks in the conveyance system resulted in a high concentrations of Cr(VI) in the groundwater in the 100-D southern plume. Disposal of large volumes of reactor cooling water to cribs and trenches and smaller releases of sodium dichromate solution resulted in Cr(VI) contamination of the groundwater in the northern portion of the 100-D Area.

From startup of the DX P&T system in 2010 through the end of 2015, the system has treated over 5,776 million L (1,526 million gal) of groundwater and has removed 1,488 kg (3,280 lb) of Cr(VI). During 2015, the DX system included 46 extraction wells and 11 injection wells (Figure 2-9). Treated water is returned to the aquifer through the injection wells.

The DX P&T system utilizes ResinTech SIR-700 resin to bind Cr(VI) as influent groundwater flows through tanks in the treatment facility. The new resin does not need to be replaced as often as the previous resin type, saving time and money. Resin change for DX vessels have only had to be performed once so far since the DX P&T started operations. The resin change-out to replace the resin in the first vessel of each of the six DX P&T IX trains started in August 2014 and completed in April 2015. The DX P&T system improved the groundwater treatment capacity along the river and is a key component in DOE's strategy for keeping Cr(VI) from entering the Columbia River. Changes in concentrations and overall trends are discussed in Section 2.2.3.

2.2.1.1 DX Pump and Treat System Configuration and Changes

The annual evaluation of the plume capture from 2014 (DOE/RL-2015-05, *Calendar Year 2014 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*) was used to identify areas along the Columbia River where additional plume capture was needed. In addition, the evaluation identified areas where Cr(VI) concentrations were declining slower than in other areas. New wells were considered for those areas to improve mass removal and plume capture. A summary of the 2015 system modifications and the effect of those changes to the plume are discussed below.

The DX P&T system changes in 2015 (Figure 1-3 in Chapter 1) include the following:

- Well 199-D5-154 was placed in operation as an extraction well in the 100-D northern plume. The well was drilled in 2013 as an extraction well, but was not connected to the system until 2015 due to limited association with waste site remediation. Well 199-D5-154 began extracting groundwater for treatment in February 2015. The increased extraction flow has improved the capture and mass removal in that area. Well 199-D5-154 has been operating at 151 to 170 L/min (40 to 45 gal/min).
- Well 199-D5-159 was drilled and connected to the DX system in 2015. The well went into service as an extraction well in July 2015 and operates at about 132 L/min (35 gal/min). Well 199-D5-159 was installed to increase mass removal from the northern plume. The concentrations are slowly declining at this location, with results of 60 μg/L at the end of 2015 compared to 97 μg/L in March 2015.
- Monitoring well 199-D5-34 had increasing concentrations of Cr(VI) and was connected as an extraction well in August 2015. The well operates at about 132 L/min (35 gal/min). Concentrations in well 199-D5-34 declined from 614 μg/L in May to 238 μg/L in December 2015.
- New well 699-93-48C was drilled and connected to the DX system as an injection well in 2015. This well was installed primarily for the disposal of extraction water. The well went into service in late August and operates at an average rate of 287 L/min (76 gal/min).

The DX P&T system will continue to be optimized using available source area data; groundwater monitoring data; updated contaminant fate and transport modeling results; and extraction/injection well performance data.

2.2.1.2 Treatment System Performance

The DX P&T system operated full time throughout 2015. Table 2-2 presents the summary of groundwater extracted, mass removed, and system performance for the DX P&T system. The DX P&T system extracted 1.48 billion L (391 million gal) of water in 2015, an increase of nearly 31 million L (82 million gal) from 2014. The system removed 85 kg (187 lb) of Cr(VI) during the reporting period, compared to 179 kg (394 lb) in 2014. Since 2013, Cr(VI) mass removal has been cut by nearly one half in each consecutive year. The ongoing reduction in total Cr(VI) mass removed is primarily a result of rapidly declining Cr(VI) concentrations in the high-concentration areas, such as the middle of the 100-D southern plume.

The influent and effluent concentrations for the treatment systems are shown in Figure 2-10. The average influent Cr(VI) concentration in 2015 was 53.3 μg/L, a decline from the 2014 average of 144 μg/L. The effluent concentration was usually below the laboratory detection limit for 2015, with a maximum reported value of 7 μg/L. The average reported effluent concentration was less than 2 μg/L. The average removal efficiency for 2015 was 96 percent, and the system operated at an average rate of approximately 2,818 L/min (744 gal/min). The influent concentration predominantly reflects the concentrations from extraction wells 199-D5-39 and 199-D5-104, which extract from the southern plume hot spot. The declining influent concentration trend is a result of significant mass removal in that area. Well 199-D8-95 had Cr(VI) concentrations of 270 µg/L on December 28, 2015, and therefore also contributes a substantial amount to the DX influent concentrations.

Figure 2-11 shows the system availability for the reporting period. The system operated over 99 percent of the time in 2015, with short downtimes for corrective maintenance. As reflected in Figure 2-11, the total flow rate through the DX P&T system (in terms of percentage of system capacity) is reduced slightly during periods of system and well maintenance and reconfiguration of piping.

Table 2-3 presents the pumping flow rates and total run-time for the extraction and injection wells currently active in the DX P&T system. The flow rate was calculated by dividing the total volume extracted for the period by the hours of pumping. Figure 2-12 shows the hydrograph for the Columbia River at the 100-D and 100-H Areas. Operational downtime of extraction and injection wells due to downtime (e.g., low water in wells during low river stage, repair, and/or maintenance) is reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.

Several wells had low operational run-time percentages during 2015. Wells 199-D5-20, 199-D8-55, 199-D8-73 had low run times (less than 80 percent) due primarily to low water levels within the wells. These wells are located near the shoreline and are responsive to changes in river stage, which was lower than normal during spring and summer 2015. Injection well 199-D8-99 was turned off in August 2015 in response to low river stage. The well has remained turned off because the plan for fiscal year (FY) 2016 is to convert the well from injection to extraction. Extraction well 199-H4-82 had a low run-time due a faulty pump controller, which was replaced.

The run time for wells added to the system in 2015 was also low, since these wells were not operational for the entire year. A list of the new wells is provided in Section 2.2.1.1. Injection wells 199-D2-12, 199-D2-10, 199-D8-94, and 199-D-93, which have limited injection capacity at high river stage, are out of service. These wells are to be converted to monitoring wells.

2.2.2 HX Pump and Treat System

The HX P&T system (Figure 2-13) became fully operational in 2011. During 2014 and 2015, the system capacity was upgraded from 3,000 L/min (800 gal/min) to 3,407 L/min (900 gal/min). Overall, however, the water available in the aquifer limits the throughput volume. The design of the HX P&T system is described in SGW-43616, *Functional Design Criteria for the 100-HX Pump and Treat System*. The design and operational philosophy optimizes containment along the river, and containment and removal of the mass in areas with higher contamination. Since startup of the HX P&T system in 2011 to the end of 2015, the system has treated over 5,200 million L (1,374 million gal) of groundwater and has removed 118 kg (260 lb) of Cr(VI). The HX P&T system included 34 extraction wells, 16 injection wells (Figure 2-14) in 2015.

ResinTech SIR-700 is used to treat the Cr(VI) as it flows through tanks in the HX treatment facility. This is the same technology that is used at the DX P&T system. The resin capacity at HX has not been exceeded and replacement of resin in the IX vessels has not been necessary since startup of the HX P&T, due mostly to the lower concentrations at HX.

2.2.2.1 HX Pump and Treat System Configuration and Changes

As with DX, the 2014 capture analysis was evaluated to determine system modifications needed during 2015. A summary of the 2015 system modifications and the effect of those changes to the plume are discussed below. Multiple well realignments and system additions were made during 2015.

Well realignments are focused on several goals: (1) isolating the H Reactor area from the plume migrating across the Horn, (2) shifting pumping areas to those with higher Cr(VI) concentrations, and (3) allowing rebound in the reactor area in order to determine if residual sources are present. Realignment included turning off several extraction and injection wells within the reactor area and converting wells from injection to extraction or from extraction to injection, depending on the location. The HX P&T system changes in 2015 (Figure 1-3 in Chapter 1) included the following:

- Three extractions wells located on the north tip of the Horn were converted to injection (199-H1-6, 199-H1-25, and 199-H1-27). This change in configuration has pushed the plume to the south, thereby shrinking the footprint.
- Two new injection wells (199-H6-7 and 199-H6-8) were installed to the south of 100-H to allow for disposal of large volumes of water and to prevent the plume from migrating to the river. These two wells are each capable of accepting over 454 L/min (120 gal/min), but their flow rates are limited by the amount of water available. This realignment, along with the realignment of well 199-H4-74 (discussed below), has resulted in the plume being cut-off from the river in that area.
- Well 199-H4-74, located south of 100-H, was converted from injection to extraction. The realignment, as well as other system reconfigurations, was intended to prevent the plume from migrating to the river. Concentrations in well 199-H4-74 are slowly increasing as the plume appears to be moving towards the well.
- Well 199-H6-2, located south of 100-H, was also converted from injection to extraction. The conversion was intended to work in combination with the other well realignments and system changes to ensure river protection in that area. However, well 199-H6-2 has not yielded sufficient flows to maintain operations and is currently turned off. In addition, the Cr(VI) concentrations in the well remain low. The water levels in the well will be monitored as the river stage increases to determine if it is a viable extraction well.
- Due to the realignment of wells 199-H4-74 and 199-H6-2, the injection flow rates near well 199-H3-4 have declined by 265 L/min (70 gal/min). As a direct result of less water being injected near well 199-H3-4, the extraction rates at well 199-H3-4 have declined from 492 to 227 L/min (130 to 60 gal/min), and Cr(VI) concentrations are slowing increasing from below detection to slightly above 10 μg/L.
- Flow rates within the H Reactor area were reduced, or turned to zero, since Cr(VI) concentrations have been consistently low in this area for several years. This modification affected extraction wells 199-H4-69 and 199-H4-70, as well as injection wells 199-H4-18, 199-H4-71, 199-H4-72, and 199-H4-73. The reconfiguration was to allow for rebound in the reactor area to determine if residual sources are present. The plume shape has not changed in response to the 2015 changes, and no new areas of Cr(VI) contamination have been identified.
- Wells 199-H3-25 and 199-H3-26 were converted from injection to extraction. These two wells are on the western edge of the 100-H Area. The reconfiguration was part of the realignment to allow for rebound at the H Reactor area. The conversion was designed to prevent the plume from migrating toward H Reactor area, where concentrations are currently low.
- New injection well 699-95-45B was installed in the Horn in 2015, just south of the highest Cr(VI) concentrations. The well has been able to accept up to 454 L/min (120 gal/min) and may be capable of even higher flow rates. The injection of water appears to be moving higher concentrated groundwater toward downgradient extraction wells, including 199-H1-45, 199-H3-25, and

199-H3-26. Concentrations are increasing significantly in downgradient extraction well 199-H1-45, with Cr(VI) values increasing from 2 µg/L on June 4, 2015, to 53 µg/L by August 4, 2015, and stabilizing at that higher level. It is unclear how much impact the new injection well 699-95-45B has on the Cr(VI) concentrations at well 199-H1-45, however, since the well did not start accepting water until August 6, 2015, and the increasing concentrations in well 199-H1-45 started in early June. The change in contaminant concentrations may also be due to the effect of the well realignments (199-H1-25, 199-H1-27, and 199-H1-6) on the northern portion of the Horn.

- New well 199-H4-93 was connected to the HX P&T system in 2015 as an extraction well. The well is also down/cross gradient of injection well 699-95-45B. Flow rates in this well are low, as had been expected, but concentrations have been stable at around 65 µg/L and therefore mass is being removed. Extraction rates will be monitored in this well as water levels increase.
- Monitoring well 199-H4-86 was converted to an extraction well to target an apparently isolated area of higher Cr(VI) concentrations near waste site 100-H-46. The Cr(VI) concentrations had been inversely related to water levels in the well, fluctuating from above 80 µg/L to below detection over the course of a season, with the highest concentrations occurring during low river stage. Since its connection to the HX system, concentrations in the well quickly declined to below 10 µg/L, with no apparent seasonal component.
- Monitoring well 199-H3-9, completed within the first water bearing unit of the RUM, was converted to an HX extraction well in 2015. As a result, Cr(VI) concentrations in well 199-H3-9 declined from 179 µg/L in July 2012 to 76 µg/L in early January 2016.
- Wells 199-H1-46, 199-H4-92, 199-H5-16, and 699-97-47B were installed in 2015. These wells were installed for potential extraction use. Wells 199-H1-46, 199 H4 92, and 199-H5-16 are scheduled for connection to the HX system in 2016. Flow rates may be highly variable in these wells due to the presence of preferential channels and a thin aquifer.
- Two wells were also drilled and completed in the RUM within the Horn area: 699-97-60 and 699-97-61. These wells were installed to investigate the contaminant plume within the RUM. They were constructed for potential extraction. Cr(VI) contamination and flow rates from these wells were evaluated following well completion. Pumping rates during well development were 19 L/min (5 gal/min) and 38 L/min (10 gal/min) for wells 699-97-60 and 699-97-61, respectively. At approximately 19 L/min (5 gal/min), well 699-97-60 had over 40 feet of drawdown within the first 10 minutes and then stabilized, indicating that flow rate may be sustainable. Well 699-97-61 had a similar response to well pumping, at a slightly higher rate. Average Cr(VI) concentrations in 2015 following well completion were 2.7 µg/L at well 699-97-60 and 97 µg/L at well 699-97-61. As a result, well 699-97-61 is scheduled for connection to the P&T system during 2016. Flow rates are anticipated to be less than 75 L/min (20 gal/min).

2.2.2.2 Treatment System Performance

The HX P&T system extracted 1,122 million L (296 million gal) of groundwater from the 100-H Area in 2015, which is essentially the same volume of water treated since 2012. The system removed 24.9 kg (55 lb) of Cr(VI) during the reporting period, compared to 23 kg (50.7 lb) in 2014. The mass removed during 2015 was essentially the same as the amount removed in 2014. The slight increase was primarily due to the connection of well 199-H3-9 to the system, increasing the mass removal from the RUM unit. This increase was offset by the slight decline in overall Cr(VI) concentrations. A summary of operational parameters and total system performance for the HX P&T system is presented in Table 2-4.

The average influent Cr(VI) concentration in 2015 was 23.3 µg/L. The average effluent concentration for the reporting period was less than 2 µg/L. The influent and effluent concentrations for the treatment systems are shown in Figure 2-15. The average removal efficiency for 2015 was 95.0 percent. The HX system operated at an average rate of 2,138 L/min (564 gal/min) during 2015. The decline in system throughput is directly related to the lower-than-usual water levels during the year that limited the amount of available water in the aquifer. Slightly higher influent concentrations were observed during the winter and fall; this seasonal fluctuation is reflective of the decreased pumping rates at extraction wells closer to the river shoreline as water levels in the wells decline. In comparison, pumping rates from extraction wells 199-H3-2C and 199-H4-12C, which extract groundwater from the first water-bearing unit in the RUM, have relatively constant pumping rates and high Cr(VI) concentrations.

Figure 2-16 shows the system availability for the reporting period. The system operated at 98.6 percent of the time in 2015, with short downtimes for corrective maintenance. As reflected in Figure 2-16, the total flow rate through the HX P&T system (in terms of percentage of system capacity) was reduced during system outages, as well as during periods of low river stage, because pumping rates are reduced at extraction wells closer to the river shoreline as water levels in the wells decline with river stage. Run times were affected more by the low water levels during 2015 than in previous years due to the drought conditions in the area.

Along the northern and eastern portions of the Horn, as well as in the 100-H Area, the aquifer thickness ranges from about 0 to 6 m (0 to 20 ft), depending on the river stage. There is often less than 3 m (10 ft) of available water in the extraction wells during much of the year. As a result, pumping from these wells is unreliable during low river stage since an insufficient amount of water is present over the top of the submersible pump to allow for pump operation. Wells in this area that have lower run-times include 199-H1-32 and 199-H1-33 (Table 2-5). Modifications to the system such as alternative well construction (e.g., using horizontal wells or larger diameter wells) and manipulation of the groundwater flow regime by using injection water to push contaminants toward extraction wells are being evaluated as an overall strategy to address low water periods.

Table 2-5 presents the pumping flow rates and total run-time for the extraction and injection wells currently active in the HX P&T system. The flow rate was calculated by dividing the total volume pumped by the hours of pumping. Operational downtime of extraction and injection wells (e.g., low water in wells during low river stage, repair, and/or maintenance) is reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.

The following wells had low (less than 75 percent) operational run-time percentages in 2015: 199-H1-32, 199-H1-33, 199-H1-37, 199-H1-38, 199-H1-39,199-H1-40, and 199-H4-4. These wells are located in areas that have a thin aquifer, low flows, and periods of nonoperation during low river stage. The low run times are typical in these wells. Other wells along the river also experienced periods of low flow rates, but the pumps were operating more than 75 percent of the time. Well 199-H4-4 had low operational run times (operating between 67 and 71 percent of the time since 2013) even though the well is located along the river. The low run-times in this older well are associated with a combination of a thin aquifer in that location and potential construction constraints (i.e., the construction particulars for this 1983 well are missing details). Cr(VI) concentrations at this well were below 10 µg/L through all of 2015, except for one measurement in July at 13 µg/L, and typically have been below 20 µg/L since 2007. Well 199-H4-4 will continue to operate, as available, to provide hydraulic containment along the river.

Several other wells experienced low run-times during 2015. Well 199-H1-3 was removed from service during 2014 due to low production rates, and remains off. Well 199-H4-76, located in the Horn in an area with a thicker aquifer, also experienced reduced operational frequency during the year, primarily related to river stage. The operational run-time for extraction well 199-H4-71, located in the H Reactor area, was reduced, along with several other extraction and injection wells in that area, to allow for potential rebound in the localized area.

Eleven other wells at HX experienced low operational run times. These wells represent the well conversions from extraction to injection, injection to extraction, and new wells for both the extraction and injection portion of the system. Run times at well 199-H6-2, which was converted from injection to extraction, were lower than anticipated due to an unexpectedly low extraction rate at the well. The low flow rate, combined with low Cr(VI) concentrations, has resulted in a re-evaluation of the use for that well. Well 199-H6-2 is planned to be converted to a monitoring well in the future, and is not anticipated to be operated unless water levels in the well increase during 2016.

2.2.3 Performance Monitoring

Control of Cr(VI) in groundwater remains the principal objective of the active groundwater interim remedial action at the 100-HR-3 OU. Nitrate, strontium-90, tritium, uranium, and technetium-99 are listed in the interim action ROD for the OU (EPA/ROD/R10-96/134) as co-contaminants and are monitored as part of the remedial action. The ROD acknowledges that other (nonchromium) groundwater contaminants are not treated by the interim action remedy. Sulfate is a contaminant of interest because the secondary DWS (250 mg/L) has previously been exceeded in a limited number of wells, primarily due to sodium dithionite solution injections during the ISRM barrier installation. Sulfate has also been detected at increasing levels in monitoring wells located near the DX P&T injection wells as discussed in Section 2.2.3.3. The increases in sulfate concentrations have not occurred in the 100-H Area, primarily because HX has required less sulfuric acid for pH adjustment as a result of lower Cr(VI) influent concentrations.

Contaminant concentration data are collected each year from 100-HR-3 OU compliance wells, monitoring and extraction wells, and aquifer tubes within the OU. The sampling data are used to update the status of the plumes and to evaluate the effectiveness of ongoing remedial activities. Particular emphasis is given to data collected during the fall of each year, when river levels are low and contaminant flux toward the river is highest. Tables 2-6 through 2-8 depict the highest 2015 concentrations for Cr(VI), total chromium, nitrate, strontium-90, tritium, technetium-99, sulfate, uranium, gross alpha, and gross beta emitters detected in the 100-D Area (Table 2-6), 100-H Area, and Horn area (Table 2-7) wells, aquifer tubes, and wells completed in the first water-bearing unit of the RUM (Table 2-8). This report focuses on evaluating the analytical results for Cr(VI) being remediated through the interim action P&T systems. Further summary and analysis of the other COCs and contaminants of interest are presented in the annual groundwater monitoring report (DOE/RL-2016-09).

Tables 2-9 through 2-11 present the fall 2015 monitoring results for Cr(VI) at the 100-HR-3 OU. CERCLA system performance assessment addresses longer term changes in Cr(VI) concentrations at selected monitoring and extraction wells in the 100-HR-3 OU. Figures 2-17 and 2-18 illustrate the Cr(VI) plumes during periods of low river-stage and high river-stage in 2015 for the 100-D and 100-H Areas, respectively. The contaminant plume maps presented in this report are based on average results for samples collected either during the low river or high river stage during 2015 for each well shown. During high river-stage periods, many of the aquifer tubes become submerged and unable to sample or samples would be mostly diluted with river water, so most aquifer tubes in the 100-HR-3 OU are usually only sampled during low river stage. During 2015, however, a small subset of aquifer tubes was sampled during mid-summer. The selected aquifer tubes were those with historically higher concentrations and those with a high probability of being accessible during a higher river stage.

Aquifer tube samples collected during the low and high river-stage periods detected Cr(VI) at some locations along the length of river shore at the 100-HR-3 OU. In locations where aquifer tubes were sampled during the high river stage period, those Cr(VI) values were used for plume map development. In locations where aquifer tubes were sampled only during low river stage, the Cr(VI) values were used for both high and low river-stage plume map development (Figures 2-17 and 2-18). Contaminant plume maps were constructed by computer programs using the quantile kriging method to produce a continuous spatial illustration of the contaminant distribution, as described in ECF-HANFORD-16-0061, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2015 (CY2015) Hanford Site Groundwater Monitoring Report.*

The following subsections present the contaminant monitoring results. Further summary and analysis of contaminants and co-contaminants are presented in the annual groundwater monitoring report (DOE/RL-2016-09).

2.2.3.1 River Stage Effects

Due to low rainfall and snowfall totals during the winter of 2014–2015, drought conditions were present in most of eastern Washington State. As a result, the overall Columbia River water level was lower than usual during spring and summer of 2015. The highest river stage in 2015 was observed in two brief periods in mid-February (Figure 2-12), with a maximum water elevation at the 100-D Area river gauge of about 118.6 m (389 ft) above mean sea level (amsl). The maximum water elevation at 100-D in 2014 was nearly 120 m (393.7 ft) amsl during June 2014.

The seasonal high river stage that typically occurs in the June through July timeframe was substantially reduced in 2015 due to regional drought conditions, with the river stage at about 117.5 m (385.5 ft) amsl during most of the summer months. Low river-stage periods for calendar year (CY) 2015 were observed from late August through December. The river stage elevation during the fall was consistent with that of 2014, with the lowest river stage at an elevation of about 116.5 to 117 m (382.2 to 383.8 ft) amsl between September and November 2015.

Typically, as the river stage rises toward its peak level, the water table surface also rises in response to the change in boundary conditions at the river shore. This effect causes river water intrusion into the adjacent aquifer and a flatter groundwater gradient. During 2015, the river water levels were fairly low for most of the year. As a result, minimal bank storage due to river water intrusion and groundwater flow toward the river was exhibited, except where the P&T system resulted in hydraulic capture (discussed in Section 2.2.5).

Groundwater-specific conductance was mapped to evaluate the potential for migration of river water into the aquifer due to capture by pumping (Figure 2-19). A specific conductance level of less than 200 µS/cm is indicative of river water (i.e., the Columbia River exhibits a relative low dissolved solids load and, thus, a low specific conductance). Specific conductance of 300 µS/cm (or greater) is typical of groundwater in the former industrial operating area of the 100-HR-3 OU. Specific conductance of 200 to 300 µS/cm indicates a likely mixing of groundwater with river water.

Well locations along the ISRM barrier exhibited specific conductance less than 300 µS/cm in most locations and less than 200 µS/cm in the northern end of the barrier (Figure 2-19). The shoreline along the northern 100-D plume had specific conductance values that represented both river water and areas of mixing. At 100-H, the specific conductance was less than 200 µS/cm along the majority of shoreline. The specific conductance values are consistent with the inferred water table maps and the areas of groundwater capture (as indicated by a definable groundwater depression) as discussed in Section 2.2.4.

2.2.3.2 Hexavalent Chromium

As described in Section 2.1, the cleanup goal for Cr(VI) in groundwater discharging to the Columbia River is the current ambient water quality criterion of 10 μg/L. This is based in part on the expectation that contaminated groundwater (prior to discharging to the river) is mixed on a 1:1 basis with relatively uncontaminated water within a near-shore mixing zone along the river. Consequently, a compliance criterion of 20 μg/L for Cr(VI) in groundwater is currently applied to near-shore and compliance wells along the river.

The Cr(VI) concentrations are monitored in wells and aquifer tubes in the 100-HR-3 OU. Figures 2-17 and 2-18 show spring and fall 2015 comparison of the distribution of Cr(VI) in the unconfined aquifer in the 100-D and 100-H Areas, respectively. In wells near the Columbia River, maximum Cr(VI) levels generally coincide with low river conditions and occur in late fall to early spring. The exception is where monitoring wells are located within a source area; in this case, the contaminant concentrations increase at high river stage. Tables 2-9, 2-10, and 2-11 present the fall 2015 Cr(VI) concentrations from extraction wells, compliance wells, monitoring wells, and aquifer tubes, along with concentrations in the first water-bearing unit of the RUM.

Hexavalent Chromium in the 100-D Area

Cr(VI) concentrations in groundwater within the southern area of 100-D remained above the DWS of 48 μg/L during 2015 but continued to exhibit steadily declining concentrations. Areas with high Cr(VI) concentrations shrunk dramatically in size, with concentrations below 480 μg/L across the area by fall 2015 (Figure 2-17). The removal of high concentrations of Cr(VI) from the vadose zone and aquifer have resulted in overall reductions in Cr(VI) in groundwater.

The primary contributor to high Cr(VI) concentrations at the 100-D southern plume was the 100-D-100 waste site. The vadose zone and upper 3 m (10 ft) of the aquifer at the 100-D-100 waste site were excavated in 2014 and the beginning of 2015, removing a large portion of the contaminant source. The excavation included removing chromium-substitute calcite precipitate, which provides a slow-leaching source of Cr(VI) to the aquifer, resulting in a long-term secondary source (SGW-58416). The discovery of this mineral led DOE to remove this source material from below the water table at 100-D-100. Removal of this type of secondary source material, where present, has the potential to greatly decrease the duration and cost of groundwater remediation. The impact of source removal is evident in Cr(VI) concentrations at extraction well 199-D5-104, which is directly downgradient of the 100-D-100 waste site. Cr(VI) concentrations in well 199-D5-104 declined from 5,392 μg/L in April 2013 to 156 μg/L by December 28, 2015. The downward trend at this well, however, is showing signs of a tailing effect, likely due to the remaining source material that was identified at the base of unconfined aquifer where removal was not practical.

The areas of higher concentrations (greater than 100 μg/L) in the 100-D northern plume are primarily located near the 120-D-1 (100-D Pond) waste site, the 126-D-1 coal ash waste site, and south of the 116-DR-1&2 Trench. Elevated Cr(VI) remains in wells 199-D8-95, 199-D8-96, and 199-D8-4 (Figure 2-20). The highest concentrations in the northern 100-D plume are found in extraction well 199-D8-95, with concentrations of 270 μg/L on December 28, 2015. A new extraction well is planned in the area (upgradient from well 199-D8-95) to address the remaining elevated concentrations. Extraction from within the former coal ash waste site is not feasible due to the geochemistry of the area, which leads to calcium carbonate buildup that essentially renders the extraction well inoperable. Farther north of 199-D8-96, moderate levels of contamination have remained, regardless of the additional remediation in the area.

It is theorized that contamination may be remaining near the 116-DR-1&2 Trench causing this portion of the plume to remain at relatively constant levels. This is based on two lines of evidence:

- A Cr(VI) concentration of 148 µg/L was detected in well 199-D8-99 when the well was installed in 2010 (currently used as an injection well). No source area was identified for this contamination, but the well is located near the trench.
- Cr(VI) concentrations in nearby wells 199-D8-68, 199-D8-71, and 199-D8-91 remain near 20 µg/L (Figure 2-21).

These wells are located between the 116-DR-1&2 Trench and the Columbia River, with no other apparent source in the vicinity. As a result, the concentrations in this area should have been below detection after 5 years of injecting clean water upgradient. The continued presence of moderate to low-level concentrations may be related to a source area being masked by the injection of clean water at well 199-D8-99. To determine if the elevated Cr(VI) concentrations detected at 199-D8-99 in 2010 are associated with a plume edge or a source area near the well, the well will be converted to an extraction well during 2016.

Hexavalent Chromium in the Horn and 100-H Area. A portion of the chromium plume originated at the 116-DR-1&2 Trench and extends across the Horn to the 100-H Area (Figures 2-17 and 2-18). This plume encompasses the largest area in the 100-HR-3 OU, but concentrations in the unconfined aquifer remain consistently less than 100 µg/L, and the majority of the plume has concentrations less than 48 µg/L. Ongoing remedial activities continue to reduce contaminant levels; however, the presence of a thin aquifer limits the effectiveness of the extraction wells.

The highest concentrations in the unconfined aquifer in the Horn are present just west of the H Reactor area. In order to increase mass removal in the Horn, injection well 699-95-45B was installed to the south of extraction well 199-H4-77 in mid-2015. As expected, the Cr(VI) plume is migrating to the north and northeast in response to the injection of water at well 699-95-45B. Increased Cr(VI) concentrations have been identified in wells to the north and east (e.g., extraction wells 199-H1-42 and 199-H1-45), but the concentrations have not increased in other wells in the same area (e.g., well 199-H1-43, which has maintained a seasonal pattern) (Figure 2-22). This indicates the presence of preferential flow paths in that area. In response to the sustained increase in contaminant concentrations in well 199-H1-45, a larger pump with a higher flow-rate capability will be installed during 2016 because the well yields sufficient water.

Monitoring well 199-H1-7 is located downgradient of extraction well 199-H1-45. Concentrations in well 199-H1-7 increased in late 2015 as the plume moved toward well 199-H1-45, with a maximum Cr(VI) concentration of 96 µg/L (116 µg/L total chromium) on December 1, 2015. Concentrations at well 199-H1-7 are higher than found in upgradient well 199-H1-45. This may be related to the location of a flow path moving contaminants to the north of well 199-H1-45. The impact of this increase in concentrations was evident in the 100-H plume during low river stage only (Figure 2-18). Since injection well 699-95-45B did not begin operating until September 2015 and concentrations started increasing mid-year, it is unclear how much the increase attribute to the new injection well versus a preferential pathway. It should be noted, however, that increased concentrations have not yet been observed in downgradient aquifer tube C5682 or well 199-H4-10, which were also sampled in December 2015.

The areal footprint of Cr(VI) above 10 µg/L shrunk significantly during 2015. Along the northern portion of the Horn, the edge of the plume was moved southward, which is the result of 2015 realignments that converted extraction wells 199-H1-25, 199-H1-27, and 199-H6-1 to injection. To the south, the addition of injection wells 199-H6-7 and 199-H6-8, along with the realignment of well 199-H4-74 to extraction, has resulted in the plume being cut-off from the river. The exception to this is a small area that was already adjacent to the river prior to the realignment efforts.

Within the 100-H reactor area, several changes were made in 2015 to allow for the plume to rebound if contaminant sources remained. This included a reduction of flow at the extraction and injection wells. This flow adjustment is ongoing, and no changes to the plume shape or size have been identified to date.

Hexavalent Chromium in the Ringold Formation Upper Mud Unit. Cr(VI) contamination is present in the first water-bearing unit of the RUM in both 100-H and the Horn. Contamination has not been identified in the RUM within 100-D. Concentrations of Cr(VI) in 100-H range from 4.4 μg/L or less in well 199-H3-10 to 137 μg/L in well 199-H4-12C during 2015. The three wells with the highest concentrations (199-H4-12C, 199-H3-2C, and 199-H3-9) are connected to the HX P&T system. Well 199-H3-9 was connected in 2015 and started operations in July, with extraction flow rates fluctuating between 38 and 57 L/min (10 and 15 gal/min).

The Cr(VI) results in well 199-H4-12C, completed in the confined aquifer, exhibited significant concentration fluctuations during the latter part of 2015. When atypically low concentrations were first detected on May 4, 2015, the concentrations were suspected to be erroneous. However, on November 11, 2015, total chromium and Cr(VI) concentrations were both low (less than 5 μg/L), which indicated that the fluctuations are not due to analytical or measurement error.

Total chromium in well 199-H4-12C was the highest on August 12, 2015, at 127 μg/L (filtered sample). The highest concentration of hexavalent chromium in well 199-H4-12C was 137 μg/L (unfiltered sample) on October 5, 2015. Low concentrations of hexavalent chromium were reported in August and November 2015. Similar to the hexavalent chromium results, total chromium results from November 2015 sampling were also low. After each of these occurrences, Cr(VI) concentrations rebounded back to slightly above their previous levels.

A similar fluctuation, as was identified at well 199-H4-12C, was noted at well 199-H3-2C in mid-2015. The fluctuation in well 199-H3-2C, however, was only concurrent with the first fluctuation at 199-H4-12C (Figure 2-23). A single anomaly was also detected in well 199-H3-9 on December 1, 2015. The December analytical result from well 199-H3-9 was 45 μg/L, which was much lower than the previous result from early November or January 2016 (both at 76 μg/L). This decline occurred shortly after the November 11, 2015, decline in well 199-H4-12C. This suggests some connection between the wells across the first water-bearing unit of the RUM. Results of the aquifer pumping test planned for 2016 will be evaluated and should assist in assessing conditions at these wells.

The extraction flow rate at well 199-H4-12C during 2015 was typically at 114 L/min (30 gal/min). The flow rate has subsequently been reduced to 38 L/min (10 gal/min) to reduce stress on the confined aquifer and the potential for a connection forming between the unconfined and confined aquifers at this well.

Across the Horn, Cr(VI) concentrations in the RUM were detected above 100 μg/L in wells 699-97-48C and 699-97-61, with concentrations in October 2015 at 120 μg/L for both locations. Well 699-97-61 is scheduled for connection to the P&T system in 2016. Figure 2-24 shows the maximum Cr(VI) concentrations in the RUM wells at the 100-HR-3 OU. It should be noted that a seasonal trend has not yet been identified. Contamination has not been identified in the RUM in the 100-D Area.

2.2.3.3 Sulfate

Sulfate has been detected at increasing levels in monitoring wells located near injection wells. Groundwater that has been treated by the DX P&T system is affected by the addition of sulfuric acid, which changes the sulfate concentrations. The acid is used to lower the pH in the influent groundwater because the SIR-700 IX resin used to remediate Cr(VI) is more efficient at a lower pH. Sodium hydroxide is added to the treated groundwater prior to reinjection into the aquifer to neutralize the acid and return to pH to near neutral. However, sulfate concentrations in the effluent are near the DWS, altering the sulfate concentration of the aquifer near the injection wells. The aquifer sulfate concentrations now appear to be stabilizing in areas near the injection wells at levels above 200 mg/L but below the secondary DWS of 250 mg/L. During 2015, the highest concentrations of sulfate were in wells 199-D8-101, 199-D5-36, and 199-D5-145 (averaging near 220 mg/L), with concentrations stabilizing. Sulfate levels declined slightly in 2015 in wells 199-D2-11 (adjacent to injection well 199-D5-148), 199-D6-3 (adjacent to well 199-D6-1), and 199-D5-106 (adjacent to injection well 199-D5-42) (Figure 2-25). The increases in sulfate concentrations have not occurred in the 100-H Area. However, the injection wells are located farther from the extraction points, and the increased concentrations appear not to extend very far into the surrounding aquifer, presumably due to a buffering effect in the aquifer.

2.2.4 Hydraulic Monitoring

Hydraulic monitoring (i.e., water-level monitoring) is performed to evaluate the effect of the P&T systems on the water table and to evaluate groundwater flow direction and gradient. The hydraulic effects of the P&T systems are superimposed on seasonal fluctuations in the river levels and inland groundwater elevation to evaluate the effectiveness of providing hydraulic containment and capture of Cr(VI) plumes.

Groundwater elevation is measured during regularly scheduled groundwater sampling events, during focused events to collect elevation measurements from many wells over a short period of time, and in selected wells by automated data-logging pressure transducers placed in the wells (automated water-level network [AWLN]). A total of 58 AWLN stations are currently operating at 100-HR-3, including both the 100-D and 100-H river gauges recording water level measurements on an hourly basis. System improvements needed to obtain the optimal well configuration are discussed in SGW-53543, Rev. 1, *Automated Water Level Network Functional Requirements Document*. The number and location of monitoring wells with AWLN data improve the certainty for the hydraulic monitoring system and, therefore, the ability to determine hydraulic capture. Additional localized, dynamic water-level data are collected at each of the P&T extraction and injection wells. Manual depth-to-groundwater measurements are collected routinely during groundwater sampling missions. All of the available data are used, where applicable, to assemble the groundwater elevation maps.

Under natural gradient conditions, groundwater in the southern portion of 100-D generally flows to the west, toward the Columbia River. In the northern portion of the 100-D Area, the gradient changes to a northwesterly direction, with groundwater flow inland being more westerly, moving across the Horn toward the 100-H Area. In the 100-H Area, the natural groundwater gradient is toward the east and southeast and toward the Columbia River on the eastern side of the Horn. The groundwater velocity in the 100-D Area is generally lower than that of the 100-H Area (DOE/RL-2009-92, *Report on Investigation of Hexavalent Chromium in the Southwest 100-D Area*). Groundwater flow entering the southern portion of the 100-HR-3 OU tends to flow toward the 100-H Area. Figure 2-26 presents the March 2015 groundwater flow map, which demonstrates a mid-period river stage when the flow direction is changing. Hydraulic effects of the P&T systems in the 100-HR-3 OU (i.e., the formation of depressions at extraction wells and mounds at injection locations) are superimposed onto these broad seasonal fluctuations. Small groundwater mounds are due to the injection of treated groundwater from the P&T systems.

The water table maps for June and October 2015 are presented in Figures 2-17 and 2-18, along with the low and high river-stage Cr(VI) plumes. The effect of the P&T systems is most apparent during 2015 in areas where injection wells have created a groundwater mound, especially at DX where large volumes of water are injected into wells that are more closely spaced.

The effects of seasonal changes in river stage (and water table elevation) on contaminant concentrations in the aquifer and treatment system performance are discussed in Section 2.2.5. The water levels of the Columbia River were lower than usual during spring and summer 2015. Due to low rainfall and snowfall totals during the 2014 - 2015 winter, drought conditions were present in most of eastern part of Washington State during 2015. The highest river stage in 2015 was observed in two brief periods in mid-February (Figure 2-12). The seasonal high river stage that typically occurs in June through July time frame was substantially reduced in 2015 due to regional drought conditions. Low river-stage periods for CY 2015 were observed from late August through December (Figure 2-12).

During a typical high river-stage period, the local groundwater gradient magnitude is reduced near the river. The area very near the river may actually exhibit a flow direction reversal, with river water intruding slowly into the aquifer (i.e., seasonal bank storage). In addition, this change (i.e., increased elevation) of the boundary condition causes the groundwater inland of the river to backup during high river stage, thus creating the seasonal increase in groundwater elevation typically observed inland of the river. As the river stage declines following the seasonal freshet, the boundary condition again adjusts, the groundwater gradient steepens toward the river, and velocity increases. This condition continues until the groundwater head again equilibrates with the low river-stage condition. Seasonal groundwater elevation transients are observed up to several kilometers from the river as the water table and river stage equilibrate, although the magnitude of the increase progressively decreases with distance from the river. Figure 2-26 presents a groundwater contour map of the area, which was developed using concurrent measurements collected on March 2015 (near the 2015 maximum river-stage period). Long-term groundwater flow in 100-HR-3 remains toward the Columbia River.

2.2.5 Hydraulic Containment

This section compares the estimated extent of hydraulic containment for the 100-HR-3 OU P&T systems with the estimated extent of chromium contamination in groundwater. The assessment is based upon a joint evaluation of groundwater levels, pumping rates (extraction and injection), and water quality data. The extent of hydraulic containment is estimated using two methods:

- Water-level mapping using an extension of the hybrid universal kriging (UK)/analytic element method technique detailed in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*
- Groundwater modeling using the 100 Area groundwater model, which is documented in SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*

In each case, the estimated extent of hydraulic containment is depicted using a capture frequency map (CFM). The CFM constructed using the water-level mapping technique is referred to as an interpolated capture frequency map (ICFM) whereas the CFM constructed using the 100 Area groundwater model is referred to as a simulated capture frequency map (SCFM). In each case, the CFM depicts the frequency with which particles representing mobile groundwater and contaminants are captured at extraction wells, calculated over a series of mapped or simulated groundwater levels that represent conditions throughout the year. A frequency of 1.0 indicates that groundwater in the area is hydraulically contained under all conditions encountered during the period (i.e., groundwater is always moving toward extraction wells).

A frequency of zero indicates that groundwater in the area was not hydraulically contained under any conditions encountered during the period (i.e., at no time during the period was groundwater moving toward the extraction wells). Intermediate frequencies indicate that the groundwater was contained under some conditions, but not all.

Water-level mapping using the ICFM approach was completed using monthly averaged groundwater elevations, pumping rates, and stage of the Columbia River, which resulted in 12 water-level maps encompassing the entire River Corridor, and correspondingly 12 individual depictions of the extent of hydraulic containment for use in constructing an ICFM. Groundwater modeling using the 100 Area groundwater model was completed using monthly average pumping rates, stage of the Columbia River, and other time-varying boundary conditions. This resulted in 12 simulated groundwater level and flow fields, and correspondingly, 12 individual depictions of the extent of hydraulic containment for use in constructing an SCFM.

The ICFM and SCFM are collective estimates for the monitoring period; emphasis is placed on regions of high frequency and on comparing areas where the ICFM and SCFM are similar or where they differ. Where the ICFM and SCFM are similar, confidence is relatively high that containment is being achieved (where both maps suggest that containment is achieved); or is weak or it is not being achieved (where both maps suggest that containment is not achieved or, in most cases, where capture frequencies are very low). Where the ICFM and SCFM differ substantially, confidence is lower in the assessment of containment because one method suggests that containment is being achieved whereas the other method suggests either that containment is not achieved or that it is weak.

Figures 2-27(a) through (f) compare the estimated extent of hydraulic containment and the estimated extent of chromium contamination in groundwater for both high and low river-stage conditions for the 100-D Area as follows:

- Figure 2-27(a) and Figure 2-27(b) depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-27(c) and Figure 2-27(d) depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-27(e) depicts the groundwater flow lines from particle tracking to estimate the aquifer capture zone of the DX P&T system over a 10-year period with the 2015 flow field repeated annually, and Figure 2-27(f) overlays the capture zone flow lines with the chromium plume contours under low river-stage conditions.

Figures 2-28(a) through (f) compare the estimated extent of hydraulic containment and the estimated extent of chromium contamination in groundwater for both high and low river-stage conditions for the 100-H Area as follows:

- Figure 2-28(a) and Figure 2-28(b) depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-28(c) and Figure 2-28(d) depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-28(e) depicts the groundwater flow lines from particle tracking to estimate the aquifer capture zone of the HX P&T system over a 10-year period with the 2015 flow field repeated annually, and Figure 2-28(f) overlays the capture zone flow lines with the chromium plume contours under low river-stage conditions.

The capture flow lines in some areas may undergo a more indirect path to an extraction well, as observed in Figures 2-28(e) and (f), which reflects the effects of river stage fluctuations and aquifer hydraulic conditions on a particle flow path. Long-term transient hydraulic capture should not be confused with capture frequency. Even in areas of relatively low capture frequency, flow lines calculated under transient conditions will, in most cases, result in migration pathways that ultimately lead to capture at an extraction well. In such cases, low capture frequency is not evidence of failure to protect the river from contaminant discharges; instead, it suggests that hydraulic containment is relatively weak, and that capture may take longer to occur.

ECF-HANFORD-16-0060, *Description of Groundwater Calculations and Assessments for the Calendar Year 2015 (CY2015) 100 Areas Pump-and-Treat Report*, presents details on the specific calculations used to produce these figures depicting capture, including updates to and implementation of the 100 Area groundwater model; the methodology for water-level mapping; and the development of the ICFM and SCFM. Finally, although advanced interpolation techniques are used in developing water-level maps, confidence in these maps is heavily dependent on the density of the monitoring well network and the quality of the available data. During 2015, the extent and quality of the available AWLN data improved compared to 2014, due to station technology improvements and additional AWLN stations. However, although the interpolated water-level maps are consistent with observations and qualitative interpretations of aquifer conditions and resulting flow fields during the year, improvements to the monitoring network are required to increase confidence in these interpretations. Maintenance and data checks are being conducted on a regular basis to improve the system reliability and data quality.

2.2.6 River Protection Evaluation

The river protection status of conditions at the 100-HR-3 OU is based on assessment of the hydraulic effects of operation of the remedial action systems, along with evaluation of changes in the discharge boundary head conditions associated with the Columbia River and the inferred distribution of Cr(VI) in groundwater. Both a quantitative and a qualitative approach are used for this assessment. The assessment indicates that the river protection status improved in 2015 over the assessment for 2014.

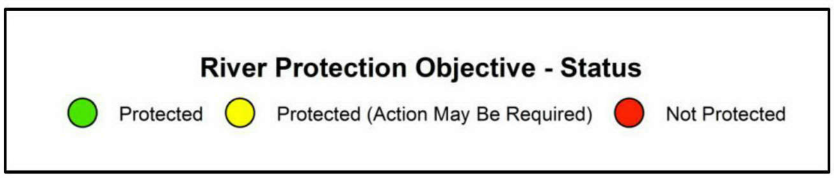
This subsection describes the river protection evaluation process and presents the results of the 2015 analysis. SGW-54209, *Systematic Method for Evaluating the Length of the Hanford Reach of the Columbia River Shoreline that is Protected from Further Discharges of Chromium from the 100 Area Operable Units (OUs)*, describes a method for evaluating progress toward attaining RAO #1, referred to as the "river protection objective." Since RAO #1 emphasizes protection of aquatic receptors, the river protection objective focuses on the performance of P&T (and other remedies) in protecting the Columbia River from further discharges of dissolved chromium from inland at concentrations above 10 µg/L. Use of this standard is consistent with Tri-Party Agreement (Ecology et al., 1989) Milestone M-016-110-T01. ECF-HANFORD-12-0078, *Assessment of the River Protection Objective: Calculation for Calendar Year 2011 (CY2011)*, and demonstrates the methods described in SGW-54209 for evaluating the progress toward attaining the river protection objective using data obtained during (or prior to) 2011.

Assessment of progress toward attaining the river protection objective for 2015 is presented in Figures 2-29(a) and (b) and Figures 2-30(a) and (b). The technical methods and process that are used to complete the calculations necessary to prepare these figures are detailed in SGW-54209. ECF-HANFORD-16-0060 presents details for the specific calculations used to produce these two figures for 2015. The results of contaminant standard and trend tests described in SGW-54209 to identify low-, moderate-, and high-concern wells are presented in Figures 2-29(a) and (b) and Figures 2-30(a) and (b) using the following symbols:

Low Concern Wells			High Concern Wells			Moderate Concern Wells		
Symbol	**Standard**	**Trend**	**Symbol**	**Standard**	**Trend**	**Symbol**	**Standard**	**Trend**
▼	Less than	Down	▲	Exceed	Up	△	Less than	Up
■	Less than	None	■	Exceed	None	▽	Exceed	Down
●	Less than	NSD	●	Exceed	NSD			

NSD = not sufficient data to calculate trend

Shoreline lengths are calculated and reported in increments of 100 m (328 ft); the results of the assessment are presented in these figures as color-filled circles of diameter equal to 100 m (328 ft). The color fill of each circle indicates the relative river protection objective status (i.e., green = protected; yellow = protected, but action may be required to ensure long-term protectiveness; and red = not protected) for the unconfined aquifer only. The following symbols depict the results of the river protection evaluation:



Figures 2-29(a) and (b) depict the assessment of progress toward attaining the river protection objective for chromium in the 100-D Area. Figure 2-29(a) shows the results of the quantitative evaluation of the objective, which is determined based upon overlay and quantitative comparison of the extent of chromium contamination with the extent of hydraulic containment. Figure 2-29(b) depicts the results of the qualitative evaluation of the objective, which is based upon the quantitative evaluation but also incorporates qualitative considerations (e.g., the duration and magnitude of hydraulic gradients along the shoreline, the locations of pumping wells, and trends in concentrations). It should be noted that for 2015, the quantitative and qualitative evaluations were identical, as it was concluded that the quantitative evaluation reflected rather accurately the conditions in the aquifer in 100-D Area (that is, effects of pumping and river stage on hydraulic gradients, plume migration and concentration trends), therefore, adjustments were not required. Based on these calculations, the river protection evaluation for the 100-D Area is as follows (note that all lengths are rounded to the nearest 5 m [16 ft]):

- Total length of shoreline adjacent to the 100-D Area: 2,800 m (9,185 ft)
- Length identified as protected: 2,400 m (7,870 ft)
- Length identified as protected (action may be required): 100 m (330 ft)
- Length identified as not protected: 300 m (985 ft)

Figures 2-30(a) and (b) depict the assessment of progress toward attaining the river protection objective for chromium in the 100-HR-3 OU/100-H Area. Figure 2-30(a) depicts the results of the quantitative evaluation of the objective, which are determined based upon overlay and quantitative comparison of the extent of chromium contamination with the extent of hydraulic containment. Figure 2-30(b) shows the results of the qualitative evaluation of the objective. Based on these calculations, the river protection evaluation for the 100-H Area is as follows:

- Total length of shoreline adjacent to the 100-H Area: 4,400 m (14,430 ft)
- Length identified as protected: 3,100 m (10,175 ft)
- Length identified as protected (action may be required): 800 m (2,625 ft)
- Length identified as not protected: 500 m (1,640 ft)

The results of the qualitative evaluations for the 100-D Area and the 100-H Area for 2015 are compared to those presented for 2014 in DOE/RL-2015-05. Table 2-12 provides a comparison of the river protection evaluation for 2014 and 2015. The effect of river-stage fluctuations on groundwater flow, combined with the aquifer response to pumping, resulted in qualitative evaluations of the river protection objective for 2015 that indicate improved system performance compared to 2014.

Quantitative evaluations of the river protection objective provide a conservative assessment of shoreline protection; qualitative evaluations for 2015 incorporate the transient effects of hydraulic capture. The CFMs describe the aggregate fate of particles, under an ensemble of steady-state conditions, each reflecting a snapshot of hydraulic gradient magnitude and direction due to pumping and fluctuations of river stage. As a result, CFMs only indicate the relative strength of hydraulic containment and not a depiction of actual transient hydraulic capture patterns. CFMs provide an effective metric to evaluate the relative strength of the capture zone, but they should not be considered an absolute indicator of hydraulic containment success or failure. Even during months of steeper hydraulic gradients near the shoreline, groundwater flow velocities result in actual plume migration expected to occur over very short distances. Relative dissipation of hydraulic gradient magnitude in subsequent months results in even slower plume migration and transient hydraulic containment. Capture can, and does, occur in areas where CFMs indicate relatively low capture frequency.

The chromium plume depiction for 2015 illustrates that implementation of well realignments, combined with moderate river stage fluctuation and short-duration high river-stage conditions, has translated into increased hydraulic containment. Comparison of the chromium plume depictions for 2014 and 2015 indicates a consistently increasing number of shoreline segments where chromium concentrations are below the aquatic standard, including in areas of lower capture frequency. Acknowledgement of these processes is reflected in the qualitative evaluation results.

2.2.7 Comparison of Simulated to Measured Contaminant Mass Recovery

Comparison of the ICFM and SCFM provides comparative depiction of the hydraulic simulation capabilities of the flow component of the 100 Area groundwater model. A similar qualitative comparison can be made for the transport component of the 100 Area groundwater model by comparing simulated and measured rates of contaminant mass recovery.

Figure 2-31 presents a comparison of the monthly and cumulative mass of chromium that was recovered throughout 100-HR-3 OU at the DX and HX P&T systems for 2015, as determined using actual influent concentrations and flow rates versus the mass recovery simulated using the 100 Area groundwater model. For the HX P&T system, mass recovery is presented showing the results (a) with extraction from the RUM wells included in the plot and (b) with the mass from the RUM wells excluded from the measured recovery plot, since the groundwater model addresses the presence of chromium in the unconfined aquifer only. As indicated in Figure 2-31, the majority of mass recovered at the HX P&T system originates in the RUM aquifer. For this simulation, the initial distribution of chromium in groundwater was assumed to be the low river-stage depiction of chromium for 2014, reflecting data collected during the period from September 1, 2014, to January 15, 2015, as presented in ECF-HANFORD-15-0003, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2014 (CY2014) Hanford Site Groundwater Monitoring Report.*

The model typically under-predicts the mass of chromium that was recovered by each system. ECF-HANFORD-16-0060 presents graphs comparing the simulated and measured mass recovery at each individual extraction well for the HX and DX P&T systems, which generally compare well to the simulated results presented in Figure 2-31. In each case, however, there are system-specific and systematic conditions that might lead to differences between the simulated and measured values, most notably the groundwater model assumption that no continuing sources are present.

At the DX P&T system, chromium mass immediately downgradient of the 100-D-100 waste site may be under-represented in the initial conditions of the numerical model. Mass recovery at wells D5-104 and D5-34 suggests that higher chromium concentrations are present in the aquifer near those wells, compared to the initial plume for the simulation. This is likely due to persistent sources that have been identified in 100-D. The investigation at the 100-D-100 waste site (SGW-58416) indicated that chromate-substituted calcite remaining in the periodically rewetted zone soil and aquifer sediment provides a potential source of ongoing release of Cr(VI) into groundwater. Since the simulated mass recovery reflects only the dissolved chromium distribution as delineated for low river-stage conditions in 2014, and does not include any contribution from continuing sources, the mass recovery may not correlate well in locations where a source remains. This condition may also affect the long-term model predictions of cleanup time since unaccounted mass may remain in the soil and/or the aquifer in isolated locations.

Recovery data from recovery wells near the northwestern end of the ISRM (e.g., 199-D4-96, 199-D4-97, 199-D4-38) indicate a number of minor concentration excursions that are not reflected in the simulation results, and that contribute to the small mass-recovery difference between the measured and calculated values. This could be due to higher concentration levels in the aquifer in the area upgradient of those wells, which is not reflected in the initial conditions used in the simulation. However, the results of the river-protection evaluation suggest strong hydraulic containment in that area.

Finally, comparison of the simulated and measured mass recovery for wells located near the high-concentration zone in D-North, indicates that higher concentrations are likely present closer to the downgradient wells (e.g., 199-D8-89, 199-D8-95) rather than near the inland wells (e.g., 199-D5-131). Development of the mapped distribution of initial plume in that area was primarily based on data from extraction wells and some monitoring wells that essentially define the perimeter of that high-concentration zone, with some uncertainty associated with the distribution and magnitude of the highest concentrations within that zone. In addition, potential presence of continuing sources in that greater area and contribution of such sources to the dissolved plume could also result in mass recovery differences between the simulated and measured values.

The HX P&T system removed 24.9 kg (54.9 lb) of Cr(VI) during 2015 (Figure 2-31). Approximately 9.6 kg (21.2 lb) of the mass recovered by the HX P&T system was extracted from wells completed within the RUM (i.e., wells 199-H3-2C, 199-H4-12C, and 199-H3-9), which are not simulated by the 100 Area groundwater model. The remaining mass of approximately 15.3 kg (33.7 lb) that was recorded as recovered by the HX P&T system originates from the unconfined aquifer that is simulated by the 100 Area groundwater model. In comparing the observed mass removed from the unconfined aquifer (15.3 kg [33.7 lb]) to the mass recovery simulated by the 100 Area groundwater model (11.2 kg [24.7 lb]), the comparison is more favorable (Figure 2-31). Comparison between simulated and measured concentrations at the extraction wells for the HX P&T system is presented in detail in ECF-HANFORD-16-0060. In general, the comparison between simulated and measured concentrations indicates patterns similar to those observed in the DX P&T system. Measured concentrations in the HX P&T system are much lower than those measured in the DX P&T system and, in most cases, about or below the groundwater cleanup standard of 48 μg/L. The difference between measured and simulated mass recovery should be attributed to the extent and distribution of concentrations above 48 μg/L, with the front end of that zone migrating closer to and ultimately across the axis between wells 199-H1-42 and 199-H1-45, as indicated by the 2015 plume delineation in that area. The separation distance between monitoring wells in that area resulted in a mapped plume near those wells that underestimates the highest concentrations in that area, as well as the extent of the zone of concentrations above 48 µg/L.

From a systematic perspective, differences between the simulated and measured mass recovery could result from using contaminant transport parameters in the transport model that do not exactly reflect conditions encountered in the subsurface. Simulated mass recovery estimates, however, present a useful tool for estimating the system performance over time and developing estimates of time to complete remediation, but these estimates will tend to under-estimate remediation timeframes where a continuing source is present.

2.2.8 In Situ Redox Manipulation Barrier Compliance Monitoring

The reduction-oxidation treatment zone (Figure 2-3) is approximately 680 m (2,230 ft) long, aligned parallel to the Columbia River, and is approximately 100 to 200 m (330 to 660 ft) inland from the river. The barrier includes 65 wells spaced across almost the entire width of the southern Cr(VI) plume. The treatment zone was designed to reduce the Cr(VI) concentration in groundwater to below 20 µg/L at the compliance wells located between the treatment zone and the Columbia River. Figure 2-32 shows the nitrate and Cr(VI) concentrations along the barrier for 2015.

As discussed in Section 2.1.2, a notice of non-significance shifted the groundwater remedy at the ISRM barrier to the P&T system. Groundwater at the ISRM site continues to be monitored for Cr(VI) as part of CERCLA interim action. ISRM monitoring is discussed in this report in order to provide a consolidated discussion of all interim remedies being used in the River Corridor. DO is monitored since the treatment process reduces oxygen content in the aquifer, and groundwater with depleted DO levels could harm aquatic receptors. Other groundwater constituents and properties are monitored to provide better understanding of the chemical characteristics of the plume.

2.2.8.1 Hexavalent Chromium

The ISRM barrier initially included seven compliance wells. Of these, monitoring wells 199-D4-86 and 199-D4-23 are the only remaining wells that have not been converted to extraction wells. Figure 2-33 provides Cr(VI) concentration plots for the seven compliance wells: 199-D4-23, 199-D4-38, 199-D4-39, 199-D4-83, 199-D4-84, 199-D4-85, and 199-D4-86. The 20 µg/L interim remedial action target was met in all but one of the seven ISRM compliance wells during 2015 (well 199-D4-38 had a Cr(VI) concentration of 23 µg/L in sample collected in September).

The Cr(VI) concentrations in barrier wells on the northern and southern ends of the ISRM barrier were below detection during 2015. The highest concentrations in 2015 were, as in previous years, near the process sewer outfall at wells 199-D4-22, 199-D4-25, and 199-D4-55. The highest concentration was in well 199-D4-22 at 101 µg/L on June 18, 2015. The Cr(VI) concentration in groundwater flowing across the ISRM barrier trended downward throughout the year in most locations, with some seasonal fluctuation. In well 199-D4-25, however, concentrations increased from 22 µg/L in September to 60 µg/L in December 2015. In the same area, wells 199-D4-62 and 199-D4-13, and downgradient extraction well 199-D4-85, also reported an increase in concentrations. This localized increase indicates an area of reduced barrier performance. The declining overall concentrations in the barrier vicinity are attributed to the increased effectiveness of the P&T system. Remedial action monitoring is described in DOE/RL-99-51, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In-Situ Redox Manipulation.*

Figures 2-34 through 2-37 show the Cr(VI) concentrations in the ISRM barrier for the four quarters of 2015. Cr(VI) concentrations during 2015 were the lowest in the spring (first quarter). In previous years, the concentrations were lowest in the summer (second and third quarters). This change is likely due to the atypical river stage changes during the year, where the highest river stage was during a short period in February. The greatest number of wells had concentrations over the remedial action target of 20 µg/L in the fourth quarter (Figure 2-37), which was consistent with previous years. Since groundwater flow is predominantly toward the river during low river stage and the hydraulic gradient were the highest during this period, there is less time for groundwater to react with reduced sediments in the ISRM barrier. Conversely, when the river stage is high and groundwater gradients are reversed (i.e., groundwater flow is inland from the river), water has a longer residence time in the barrier and/or previously treated water flows back to the barrier. As a result, more Cr(VI) is reduced to trivalent chromium, and the concentrations of Cr(VI) decrease. The northeastern portion of the barrier continues to have a large number of wells with concentrations greater than 20 µg/L. At the southern end of the barrier, Cr(VI) appears to be following a preferential pathway that bypasses most of the barrier. The planned installation of two new extraction wells upgradient of the barrier is intended to improve both capture of the plume and river protection. Overall concentrations in the barrier decreased during 2015 due to the ongoing remedial actions, including operation of the DX P&T system and source area removal.

2.2.8.2 Dissolved Oxygen

The DO concentrations are monitored as required by the ROD amendment (EPA/AMD/R10-00/122) and the remedial design report/remedial action work plan (RDR/RAWP) (DOE/RL-99-51). The sodium dithionite injection process reduced DO in the groundwater at the barrier to low levels. Low levels of DO are monitored to assess changes in concentration as groundwater approaches the Columbia River. Low levels of DO in the river may pose a risk to aquatic organisms. Monitoring of DO will assist in developing actions to increase the oxygen in groundwater via air sparging, or other means, if significant low values persist. The DO profile near the ISRM treatment zone is generally characterized by relatively high DO concentrations upgradient of the treatment zone, decreasing significantly through the treatment zone, and recovering to higher DO concentrations as groundwater flow approaches the river (Figure 2-7).

Overall, the DO levels near and along the ISRM barrier are increasing. The DO concentrations are typically relatively high upgradient of the treatment zone (except in the area of the former treatability test wells [199-D5-107 and 199-D5-108]), decreasing significantly through the treatment zone, and recovering to higher DO concentrations as groundwater flow approaches the river. Indicated by only a small area of low DO near wells 199-D4-19 and 199-D4-62 where the DO levels are below 3 mg/L, the barrier is becoming less effective; however, system modifications have improved the DX P&T system capture in the area. DO levels in the majority of the barrier are currently between 3 and 6 mg/L.

2.2.8.3 Sulfate

Sulfate is listed as a groundwater contaminant with a national secondary DWS of 250 mg/L (40 CFR 143, "National Secondary Drinking Water Regulations"). Sulfate is a byproduct of the sodium dithionite reaction used to establish the ISRM treatment zone. Sulfate previously exceeded the 250 mg/L secondary DWS in wells within and downgradient of the ISRM barrier as a result of the sodium dithionite solution injections. No exceedances of the sulfate DWS occurred at the ISRM barrier or elsewhere in the 100-HR-3 OU during 2015. The highest sulfate concentrations along the ISRM barrier were at 160 mg/L at well 199-D4-15.

2.2.9 Remedial Process Optimization Activities

Contractors have developed a pumping optimization model, based on the 100 Area Groundwater Model that will be used by OU scientists along with a detailed simulation display interface to evaluate the relative performance of alternative well configurations. The OU scientists will evaluate pumping configurations throughout the year and provide adjustments to flow rates and recommendations for well realignment and/or the installation of new wells. Specific remedial process activities performed at the 100-HR-3 OU during 2015 included the following:

- Installing new extraction wells at locations based on previous years' evaluation of plume capture and river protection analyses
- Designing and constructing new extraction and injection wells as high-performance wells (i.e., using high-capacity well screens and matching filter pack to screen and formation).
- Placing new and realigned extraction and injection wells in service to enhance plume capture
- Maintaining the AWLN system to ensure enhance hydraulic monitoring capacity
- Identifying low-performing extraction and injection wells for maintenance or removal from operations
- Identifying system infrastructure components to be changed to enhance groundwater extraction and injection performance
- Initially using the pumping optimization model to evaluate expected extraction/injection well effects on plume capture

2.3 100-HR-3 Operable Unit Pump and Treat Systems Costs

This section summarizes the actual costs for the 100-HR-3 OU P&T systems for 2015. The primary categories of expenditures are described as follows:

- **Capital design:** Includes design activities to construct the P&T systems, including wells, and designs for major system upgrades and modifications.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the P&T systems.
- **Project support:** Includes project coordination-related activities and technical consultation, as required, during the course of the facility design, construction, acceptance testing, and operation.
- **Operations and maintenance (O&M):** Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes the costs associated with routine field screening and engineering support as required during the course of P&T operations and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis, as required in accordance with the 100-HR-3 and 100-KR-4 OUs interim action work plan (DOE/RL-96-84).
- **Waste management:** Includes the cost for managing spent resin at the 100-HR-3 OU in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Cost includes waste designation sampling and analysis, resin regeneration, and new resin purchase.

The costs include all activities associated with the interim remedial actions, including construction of new wells and interim action performance monitoring. The 100-HR-3 OU costs for 2015 are associated with four P&T systems: HR3, DR5, DX, and HX. The cost breakdown for each of these P&T systems are shown in Tables 2-13 through 2-16, respectively. The HR3 and DR5 P&T systems were shut down in 2011; however, historical costs for these systems are included as part of the overall cost of the interim action remedy (Tables 2-13 and 2-14). Costs for the HR3 and DR5 P&T systems after system shutdown in 2011 are associated with surveillance and maintenance and decommissioning of the facilities. Costs are burdened and are based on actual operating costs incurred during 2015. Summaries of the costs for the DX and HX P&T systems are presented in the following subsections.

2.3.1 DX Pump and Treat System

The total cost for the DX P&T system during 2015 was approximately $5.68 million, which consists of the sum of the categories shown in Table 2-15. The largest single component of the total cost was $4.32 million spent during the year for O&M. The cost breakdown percentage for the DX P&T system (Figure 2-38) is as follows, in decreasing order:

- O&M – 76.2 percent ($4,322,900)
- Treatment system capital construction - 14.6 percent ($831,200)
- Performance monitoring – 4.7 percent ($264,100)
- Project support – 2.9 percent ($165,500)
- Design - 0.9 percent ($48,400)
- Waste management – 0.8 percent ($43,200)
- No field studies were performed in 2015

The cost increase from 2014 to 2015 for the DX P&T system is associated with capital construction for well realignments described in Section 2.2.1, resin disposal, and increased maintenance and performance monitoring associated with the additional wells in the P&T network.

Based on the total 2015 cost of $5,675,000, the yearly production rate of 1,482 million L (391 million gal), and 84.6 kg (186 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0038/L, or $67.05/g of Cr(VI) removed.

2.3.2 HX Pump and Treat System

The total cost for the HX P&T system during 2015 was approximately $5.03 million, which consists of the sum of the categories shown in Table 2-16. The largest single component of the total cost was $3.86 million spent during the year for O&M. The cost breakdown for the HX P&T system for 2015 (Figure 2-39) is as follows, in decreasing order:

- O&M – 76.7 percent ($3,862,800)
- treatment system capital construction - 14.1 percent ($708,600)
- performance monitoring – 4.4 percent ($221,800)
- project support – 3.3 percent ($163,900)
- design - 0.8 percent ($39,200)
- waste management – 0.7 percent ($36,800)
- no field studies were performed in 2015

The cost increase from 2014 to 2015 for the HX P&T system is associated capital construction for well realignments described in Section 2.2.2.

Based on the total 2015 cost of $5,033,000, the yearly production rate of 1,122 million L (296 million gal), and 24.9 kg (55 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0045/L, or $201.9/g of Cr(VI) removed.

2.4 Conclusions

The status of the 100-HR-3 OU illustrates that remedial progress has been achieved for the plume areas associated with each of the P&T systems currently active within the 100-HR-3 OU. The following conclusions for the OU are based on each of the RAOs.

The DX and HX P&T systems removed a significant amount of Cr(VI) mass from the aquifer in 2015. The amount of mass removed on a year-by-year basis continues to decrease as the areas of high Cr(VI) concentrations are remediated. RPO will continue, and system modifications will be conducted to target the remaining mass and increase river protection.

The combined hydraulic and water quality data evaluation suggest that the extent of hydraulic containment developed by the DX and HX P&T systems during 2015 is consistent with the design of the systems and is within expectations. Calculations suggest that the river protection objective is being achieved along the majority of the 100-HR-3 OU shoreline.

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering the Columbia River.

  Results: Capture zone analysis suggests that operation of the P&T systems is resulting in a capture frequency of 70 to 90 percent over most of the 100-HR-3 OU Cr(VI) plume at concentrations above 10 μg/L.

  The combined hydraulic and water quality data evaluation indicates that the extent of hydraulic containment developed by the DX and HX P&T systems improved in 2015. This improvement is consistent with expectations from well locations and planned extraction rates. Calculations indicate that the river protection objective is being achieved along the majority of the 100-HR-3 OU shoreline, with fewer areas being at risk. The performance of remedial action systems currently in place at 100-HR-3 OU confirms that DOE has taken the necessary measures to control the discharge of Cr(VI) into the Columbia River (Tri-Party Agreement Milestone M-016-110-T01 [Ecology et al. 1989]). The increase in protection in both 100-D and 100-H Areas is related to the addition of new wells to the P&T system, and remediation of high concentration sources, such as at 100-D-100.

  Based on the aquifer tube data for 2015, the concentrations of Cr(VI) discharged to the Columbia River within the 100-HR-3 OU continue to decline. This appears directly related to improved overall capture from system alignments. The locations where Cr(VI) discharged to the river remained generally the same as observed in previous years, although the length of shoreline where the discharges occurred decreased. The area to the north of 100-H exhibited increased capture and river protection. To the south of 100-H, river protection was greatly improved due to well realignments. Localized areas where contaminants may still discharge to the river include a small area downgradient of the 100-D northern plume, south of the ISRM barrier, a small area along the northern portion of the Horn, and in the H Reactor area.

  The DX P&T system has largely attained the RAO for river protection along the ISRM barrier and 100-D northern plume. The improvements in these areas are directly related to well field modifications, as discussed above. South of the ISRM barrier, the RAO is not currently attained; however, additional extraction is planned for that area with two new wells planned for installation. In addition, the RAO is not attained in a small area along the northern portion of the 100-D Area;

additional well realignments are planned to address this area of concern. These areas are expected to be captured by 2017.

The HX P&T system has largely attained the RAO for river protection at the 100-H Area, and the Horn. System modifications being conducted for fiscal year 2015 addressed the area of weaker protection to the south of the 100-H Area. The area within the reactor area continues to be addressed by ongoing extraction. The area to the north of the 100-H Area where the RAO is not fully attained shrunk during 2015, and additional realignments are planned.

The 100-HR-3 OU P&T systems have removed substantial amounts of Cr(VI) from the groundwater. Since startup of the DX and HX P&T systems, an estimated total of 1,606 kg (3,540 lb) of Cr(VI) has been removed from the shallow unconfined aquifer and RUM, with the DX P&T system alone removing 1,488 kg (3,280 lb) of that total.

The observed concentrations of Cr(VI) in groundwater at both the DX and HX P&T systems are declining as remediation progresses.

- **RAO #2:** Protect human health by preventing exposure to contaminants in the groundwater.

  Results: The interim remedial ROD (EPA/ROD/R10-96/134) establishes a variety of institutional controls (ICs) that must be implemented and maintained throughout the interim action period. These provisions include the following:

  - Access control and visitor escorting requirements
  - Signage providing visual identification and warning of hazardous or sensitive areas
  - Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  - Regulatory agency notification of any trespassing incidents

  The effectiveness of ICs was presented in DOE/RL-2004-56, *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions*. The findings of this report indicate that ICs were maintained to prevent public access, as required.

- **RAO #3:** Provide information that will lead to a final remedy.

  Results: Rev. 0 of the RI/FS report (DOE/RL-2010-95) was completed in October 2014. The Proposed Plan (DOE/RL-2011-111), which will lead to issuance of a ROD for cleanup of contaminated soil and groundwater at the 100-D and 100-H Areas, is currently under review.

  Additional information on the groundwater contamination at the 100-HR-3 OU continues to be gathered. Ongoing groundwater monitoring activities provide information on the changes in contaminant concentrations, as well as the spatial distribution of the groundwater plumes. Information collected during source remediation actions is assessed to provide details regarding the sources of groundwater contamination, including the persistence of source material within the aquifer and the potential for continuing contributions from secondary sources within the vadose zone for Cr(VI).

  Evaluation of information from multiple activities indicates that while the interim groundwater remedial actions at the 100-HR-3 OU have been successful at reducing Cr(VI) concentrations and reducing plume sizes across the OU, residual secondary sources likely remain. A final remedy will need to address ongoing contributions from vadose zone sources, as well as high contaminant concentrations in groundwater at or near source release areas.

2.5 Recommendations

Recommendations for the 100-HR-3 OU are as follows:

- Continue RPO activities for the DX and HX P&T systems:

- Evaluate the well network for improved efficiencies to maximize use of treatment system capacity, particularly during periods of low river stage when treatment capacity usage has historically decreased.

- Evaluate and identify adjustments to pumping rates, locations for new well installations, and/or well realignments to meet the primary objectives; control hydraulic gradients, protect the Columbia River, remove contaminant mass, and restore the aquifer.

Develop and prioritize well additions and/or realignments based upon the RPO evaluations to include in future planning for the P&T systems.

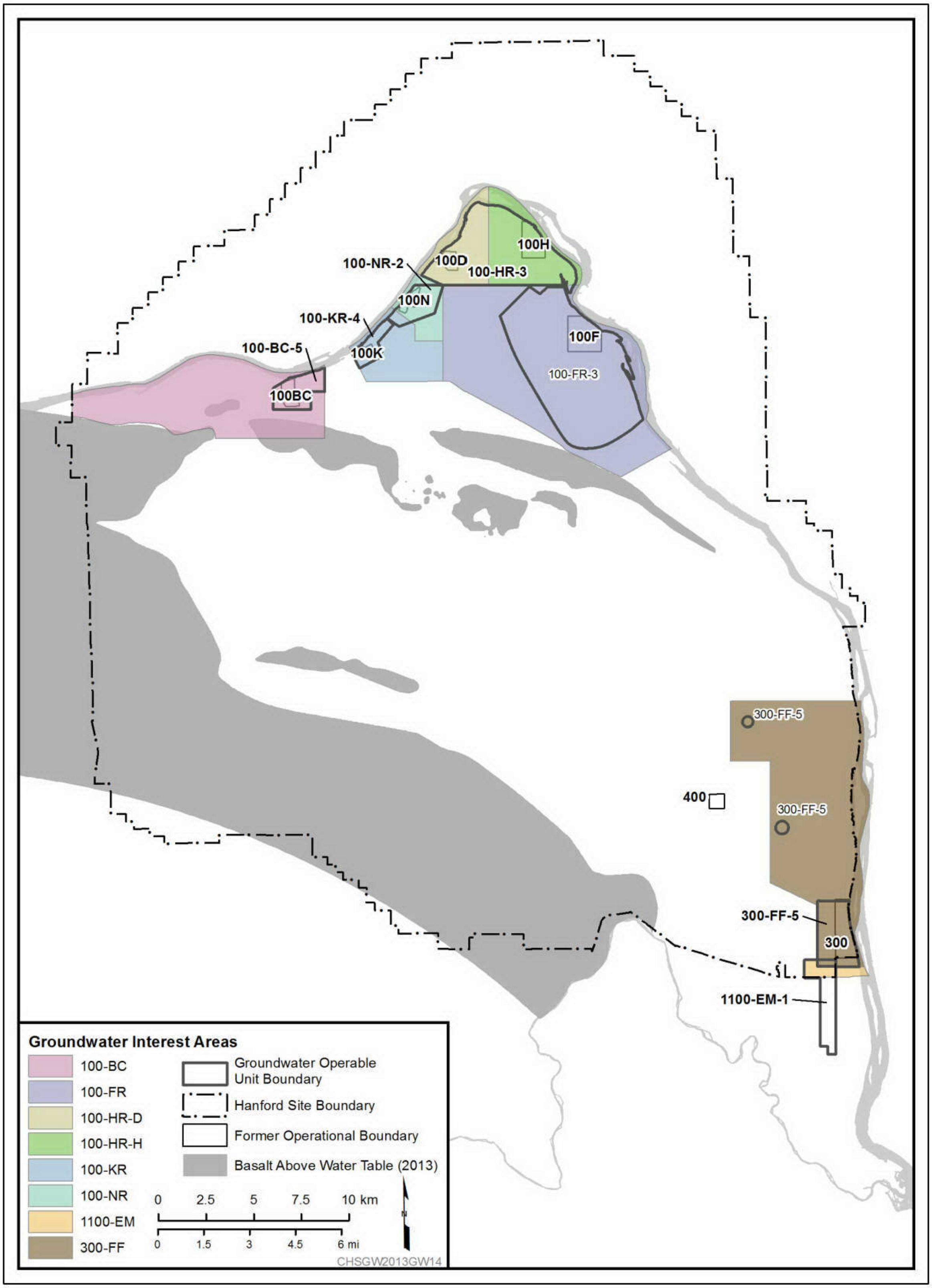


Figure 2-1. Location of the 100-HR-3 OU and Groundwater Interest Areas

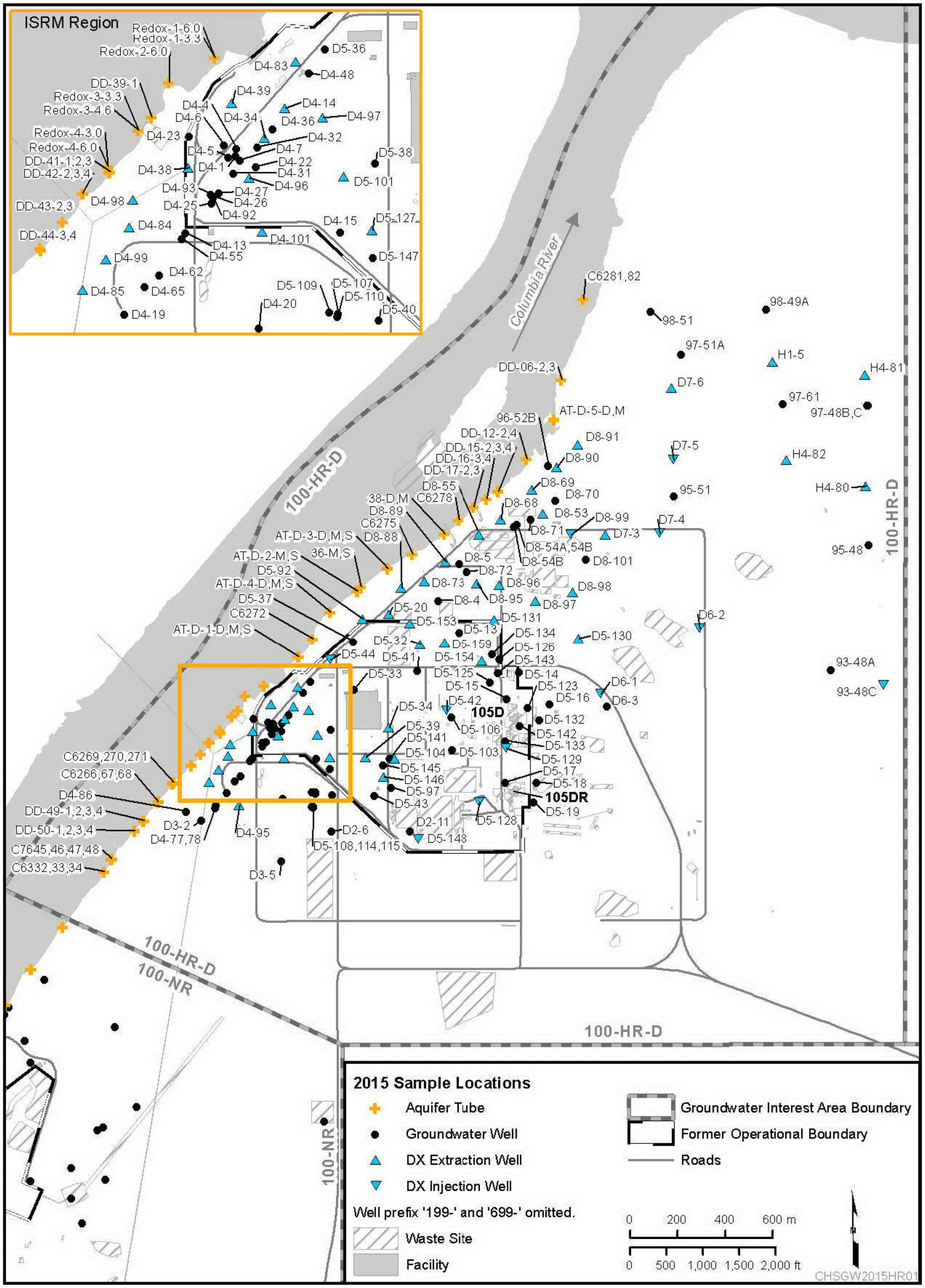


Figure 2-2. 100-D Area Wells and Aquifer Tubes

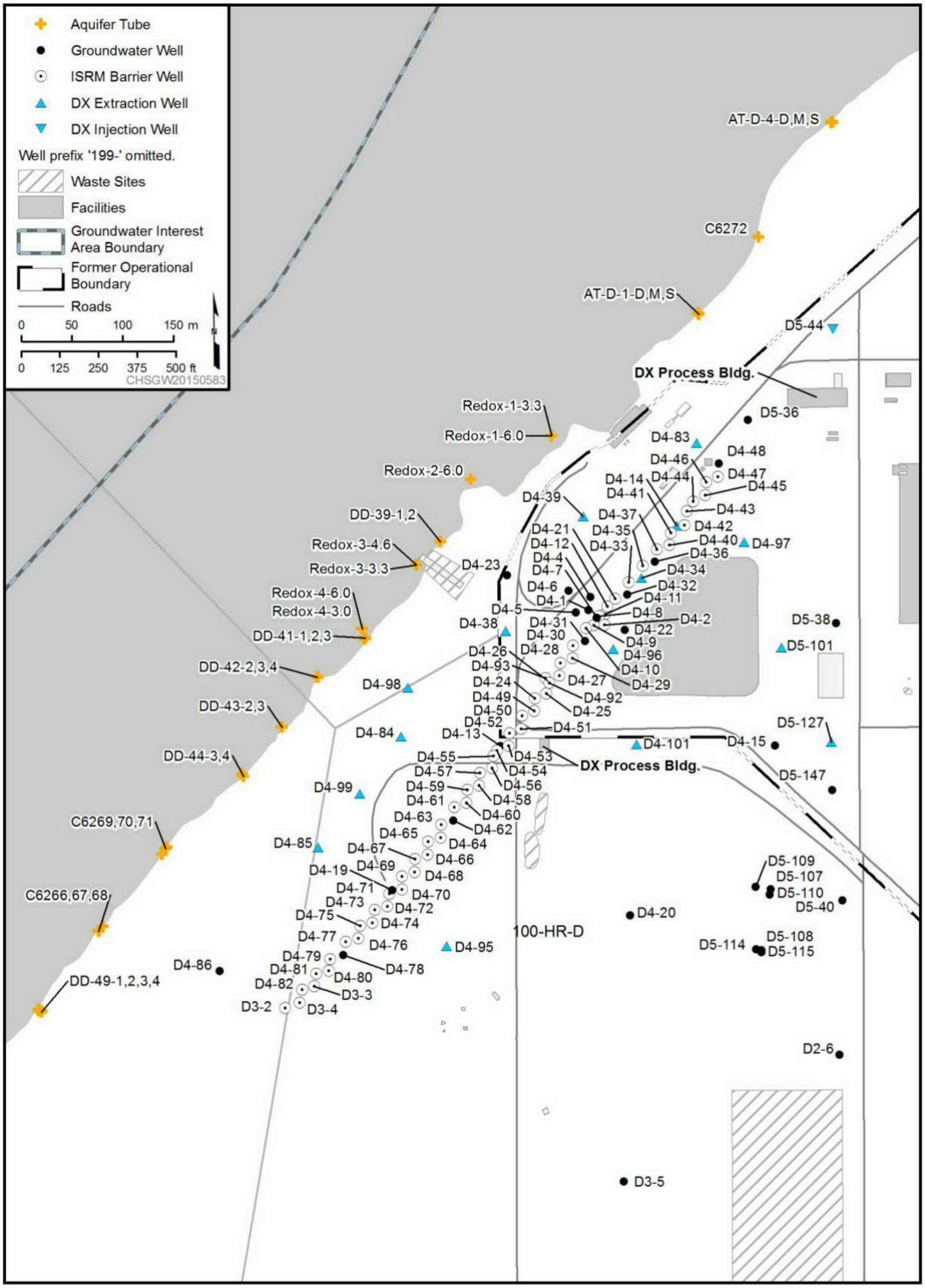


Figure 2-3. ISRM Detail Map

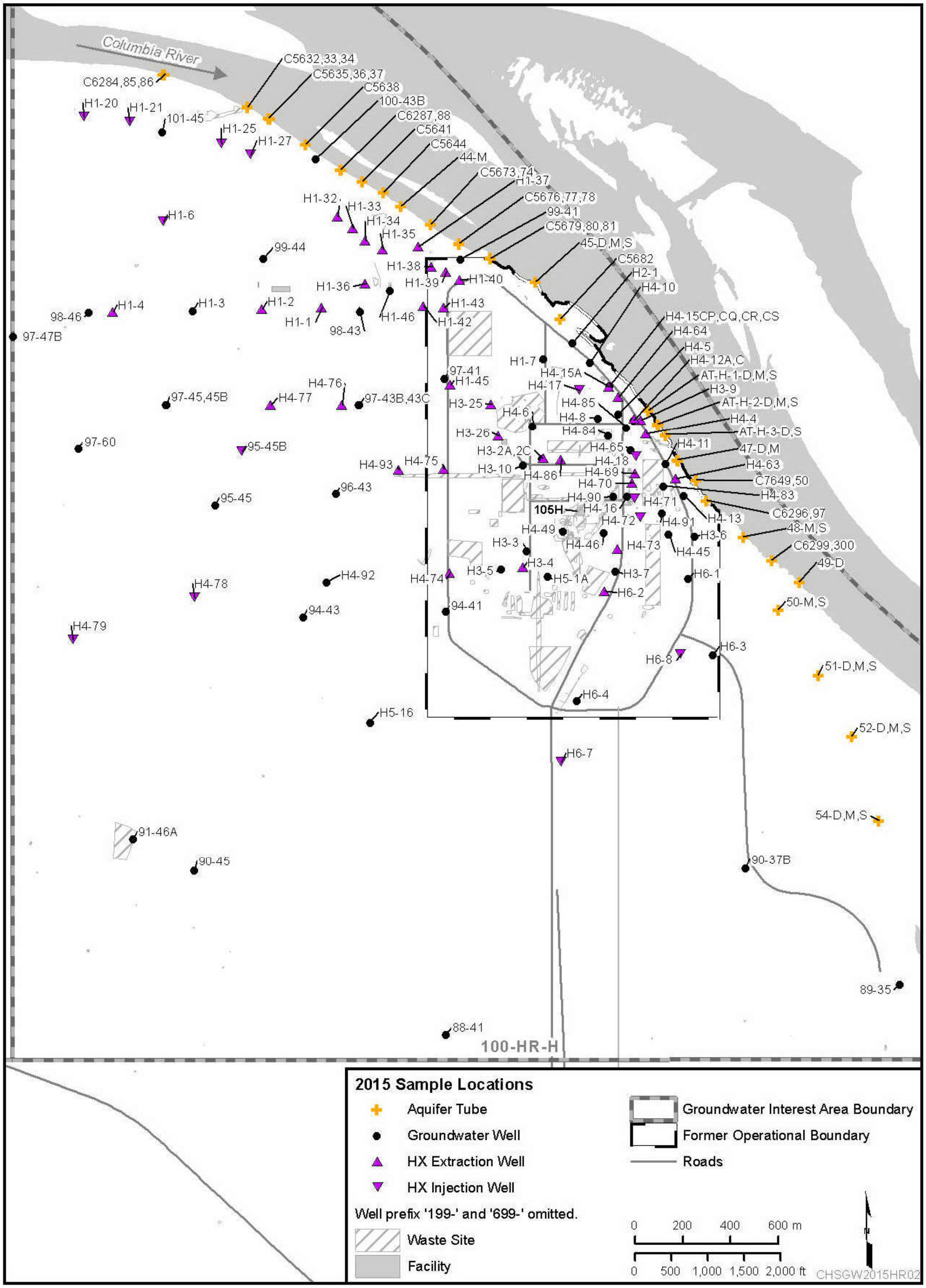
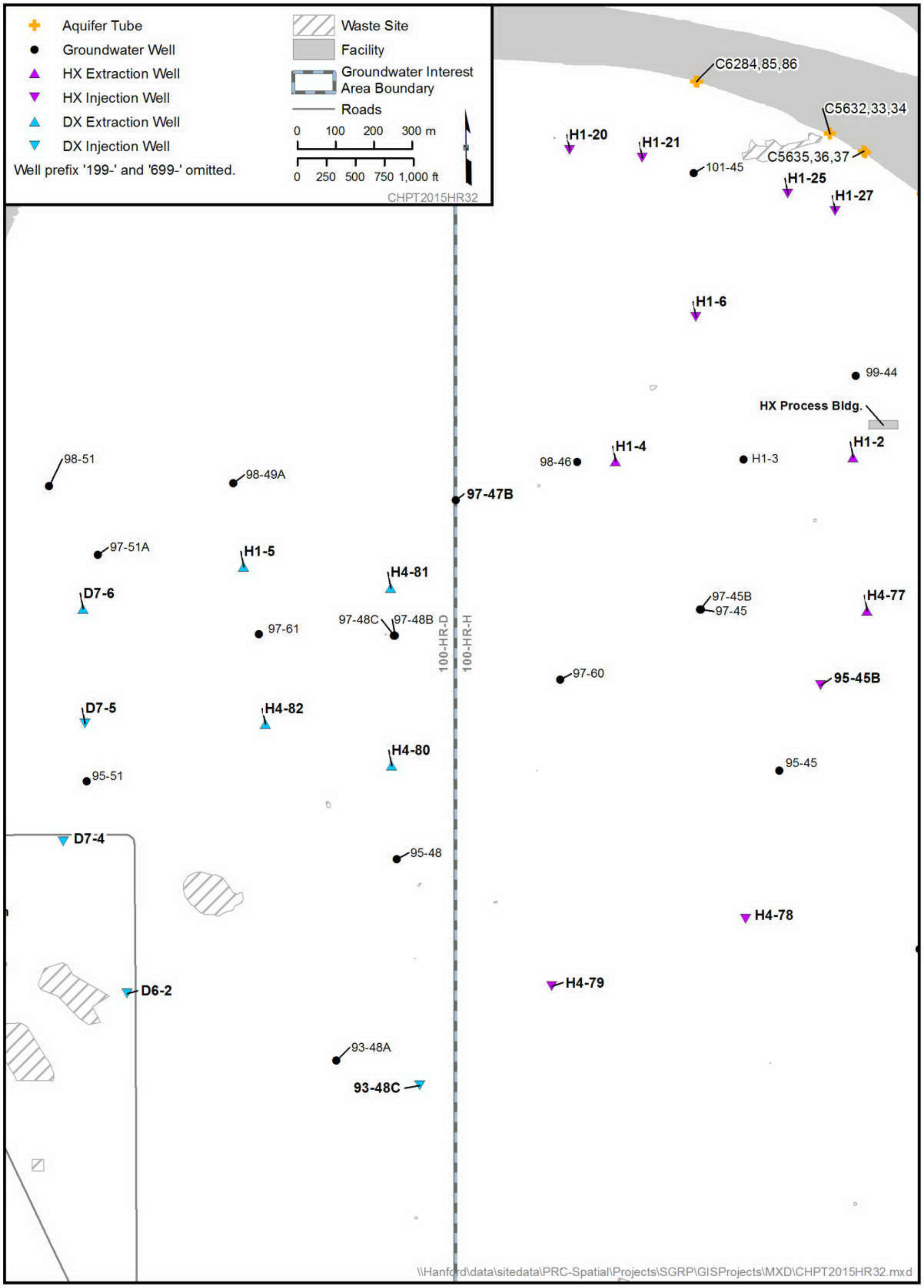


Figure 2-4. 100-H Area Wells and Aquifer Tubes

1


2 **Figure 2-5. Horn Wells and Aquifer Tubes**

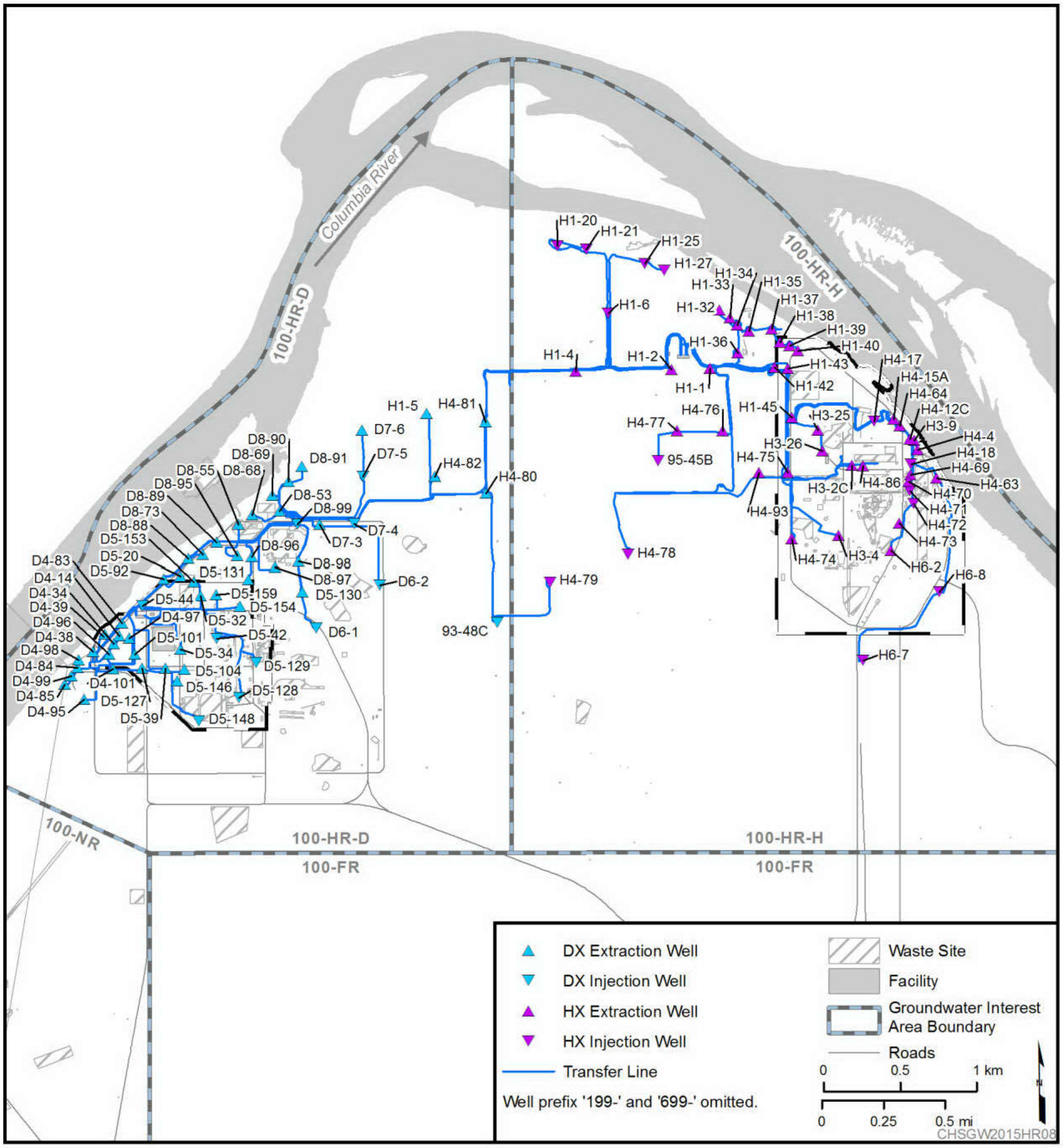


Figure 2-6. Layout of the 100-HR-3 OU P&T Systems (as of December 31, 2015)

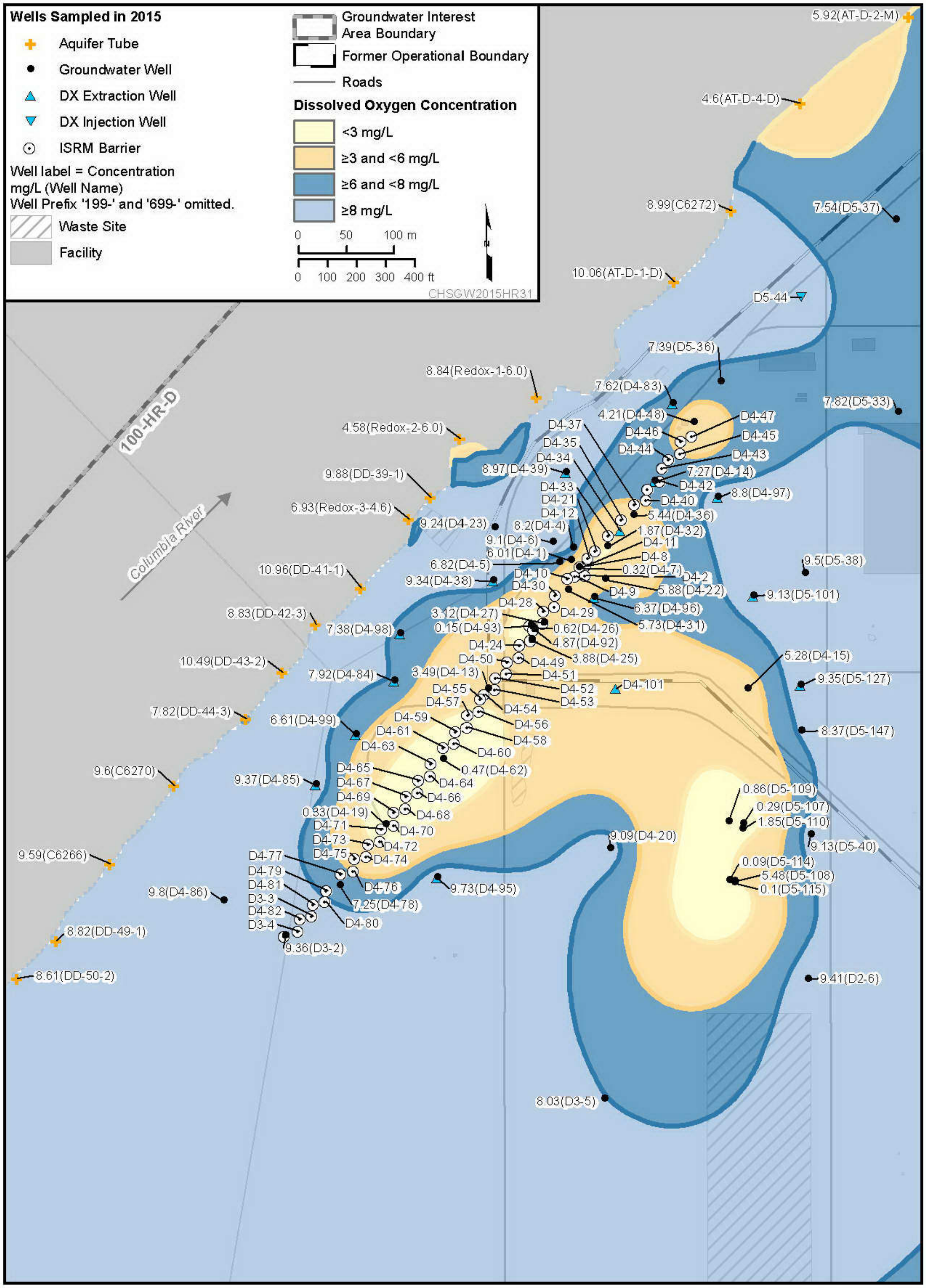


Figure 2-7. ISRM Area DO Concentrations, 2015

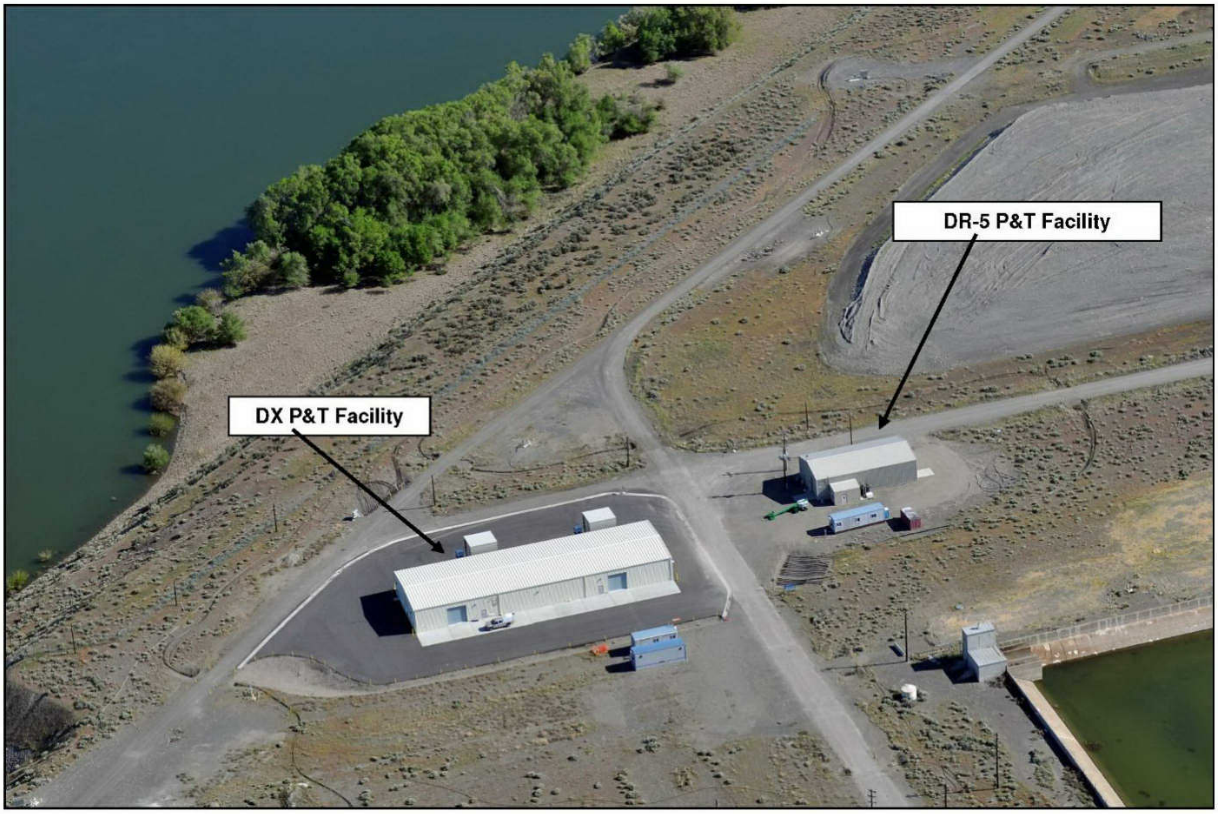


Figure 2-8. Aerial View of the DX P&T System

This page intentionally left blank.

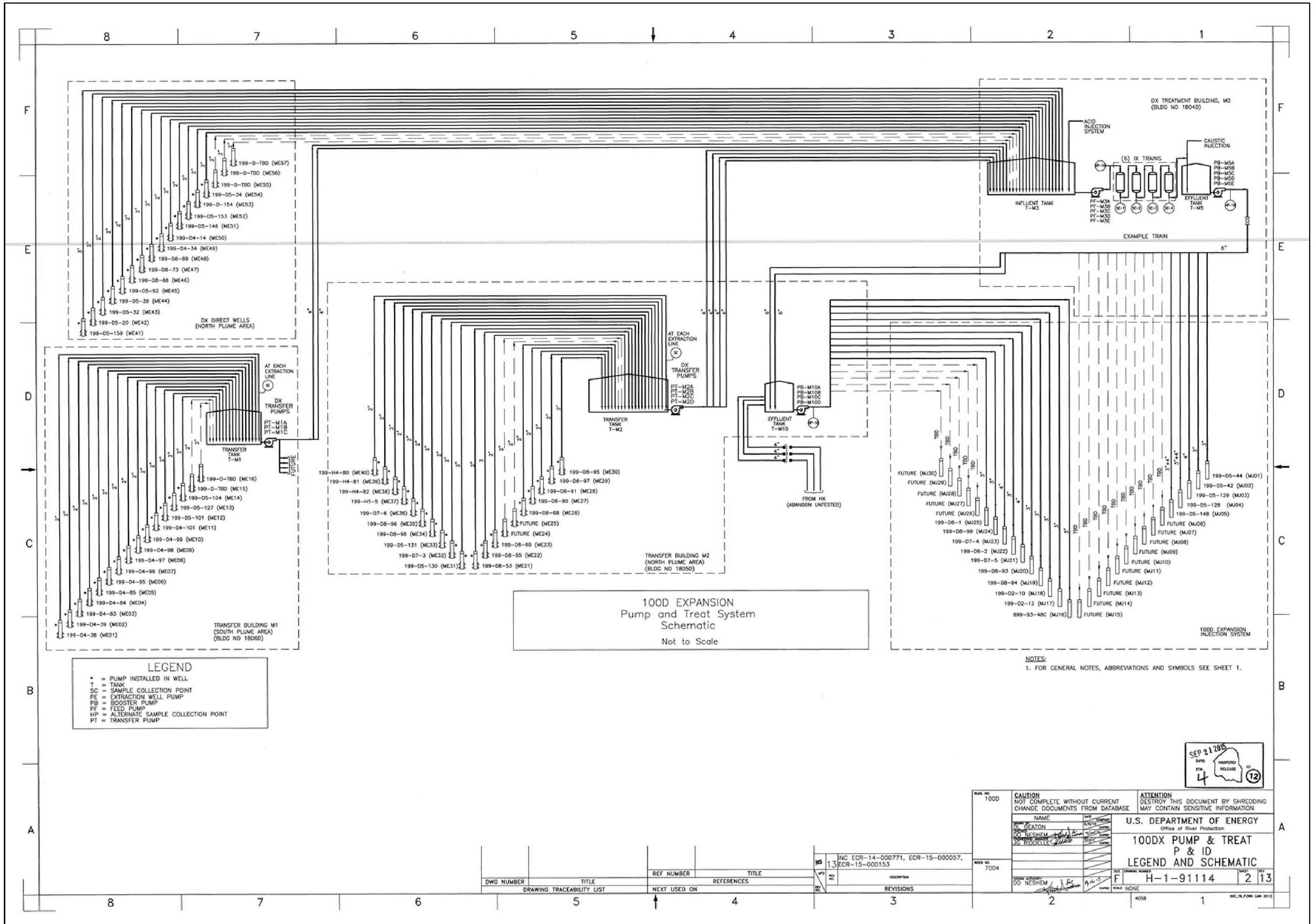


Figure 2-9. DX P&T System Schematic

This page intentionally left blank.

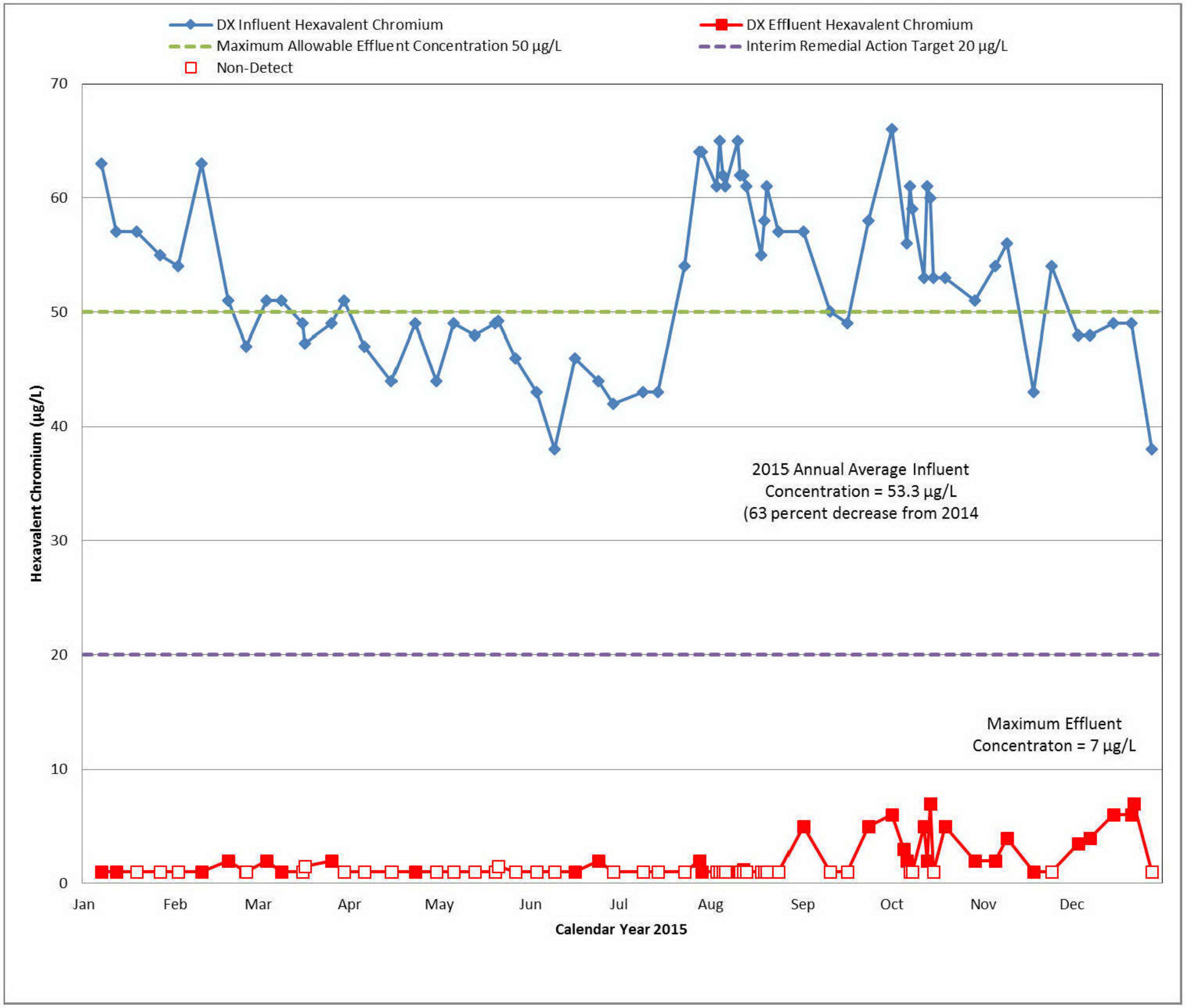


Figure 2-10. Influent/Effluent Concentrations for the DX P&T System

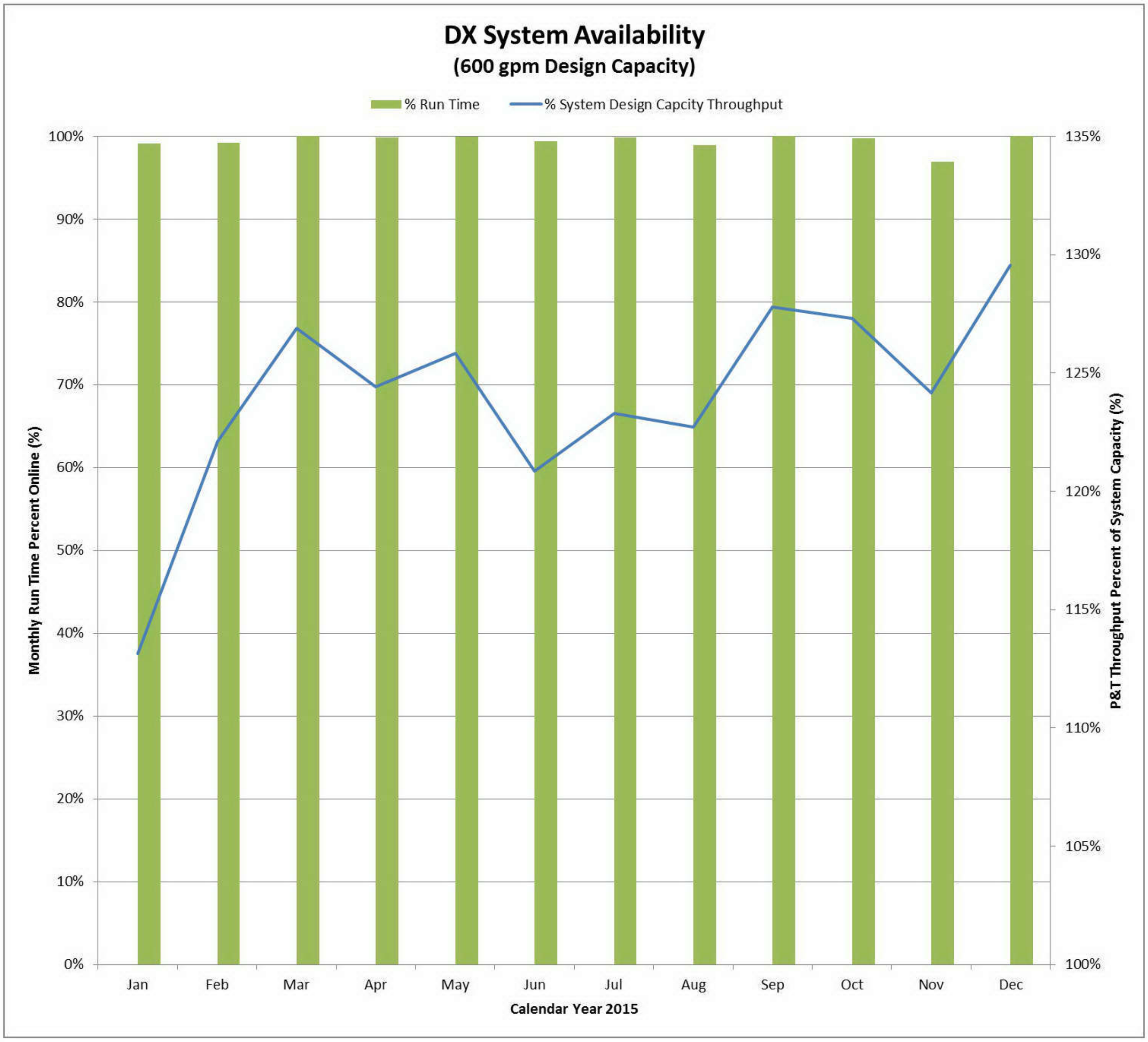


Figure 2-11. System Availability for the DX P&T System

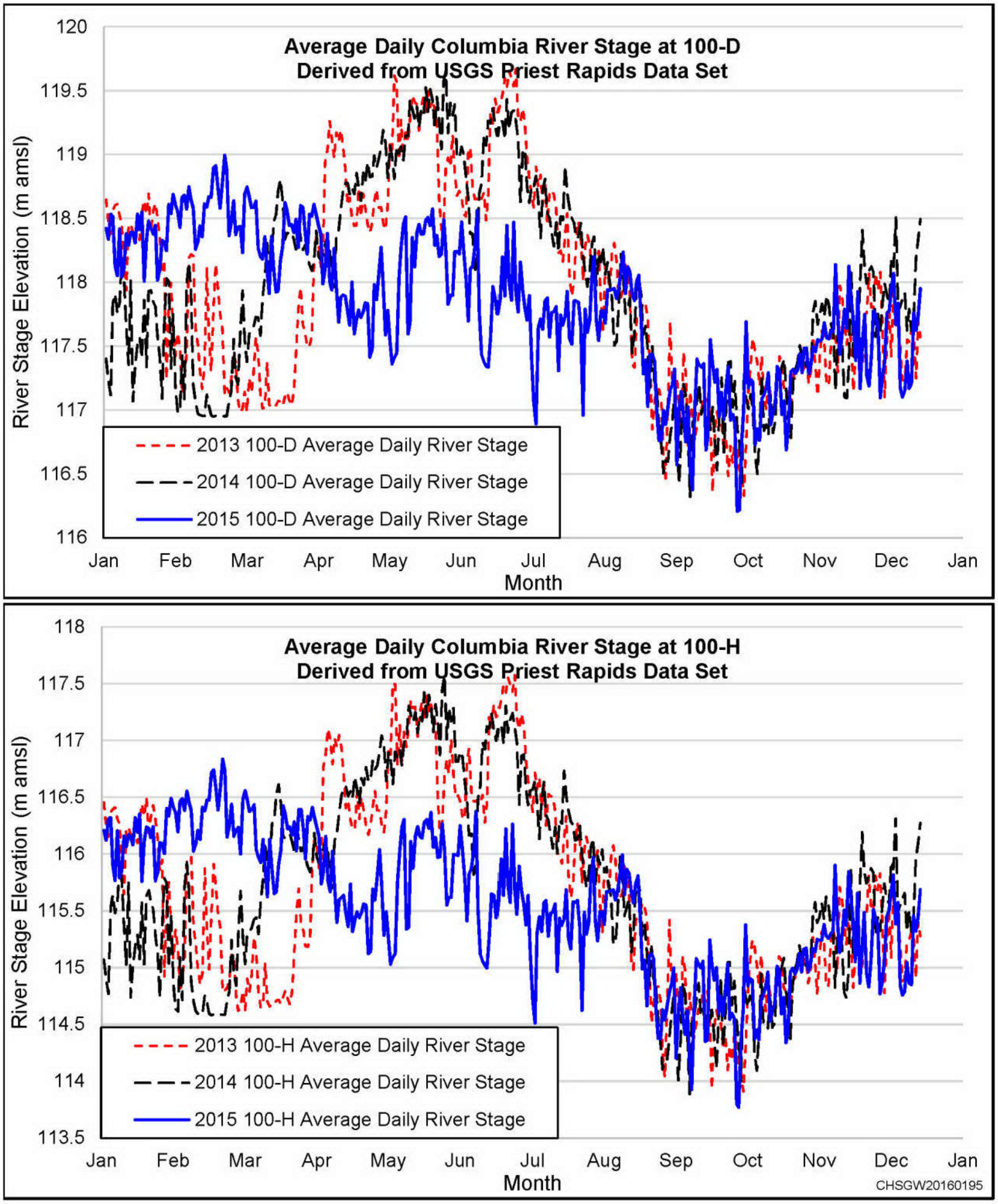


Figure 2-12. River Stage Hydrograph at 100-D and 100-H

Figure 2-13. Aerial View of the HX P&T System

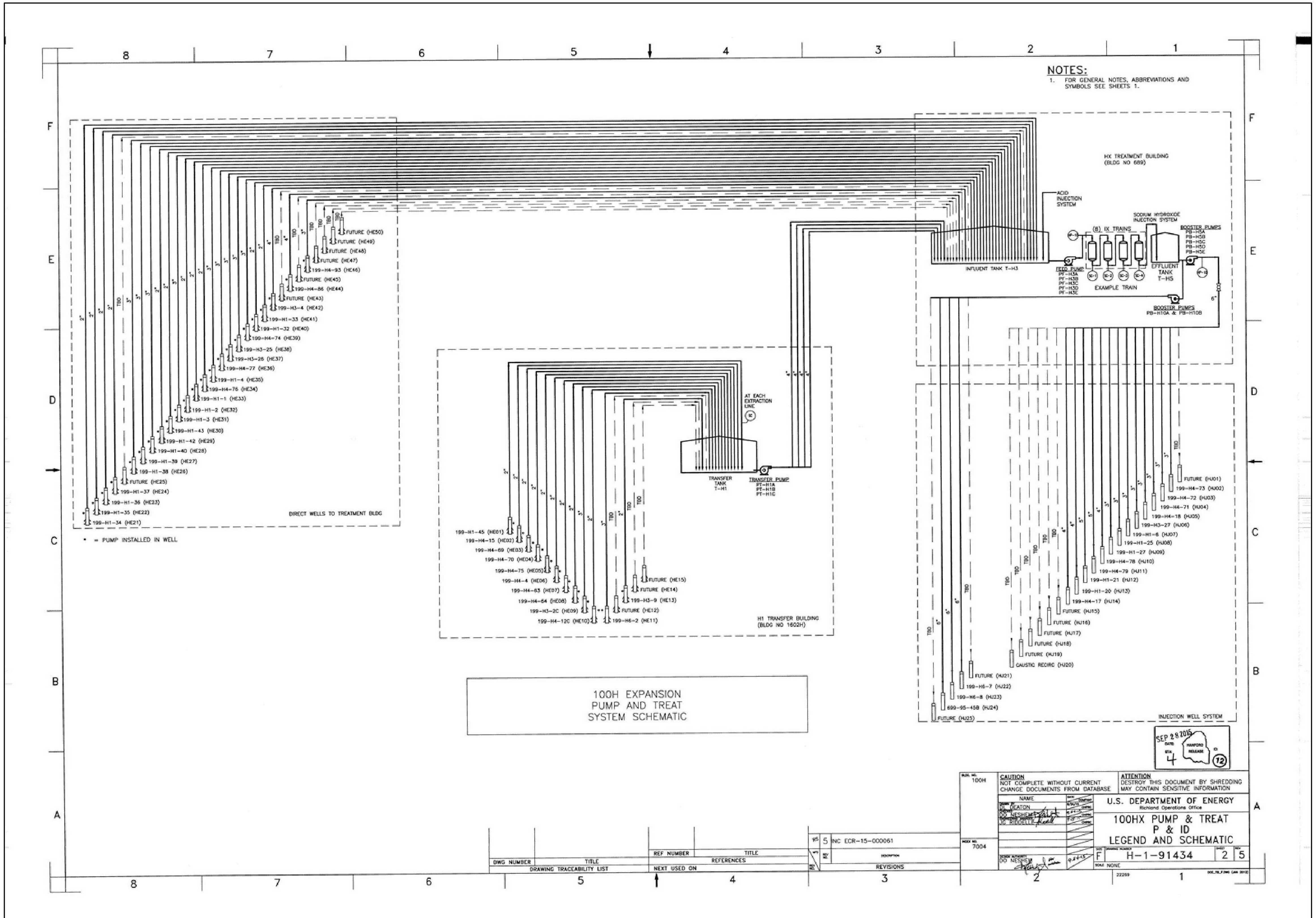


Figure 2-14. HX P&T System Schematic

This page intentionally left blank.

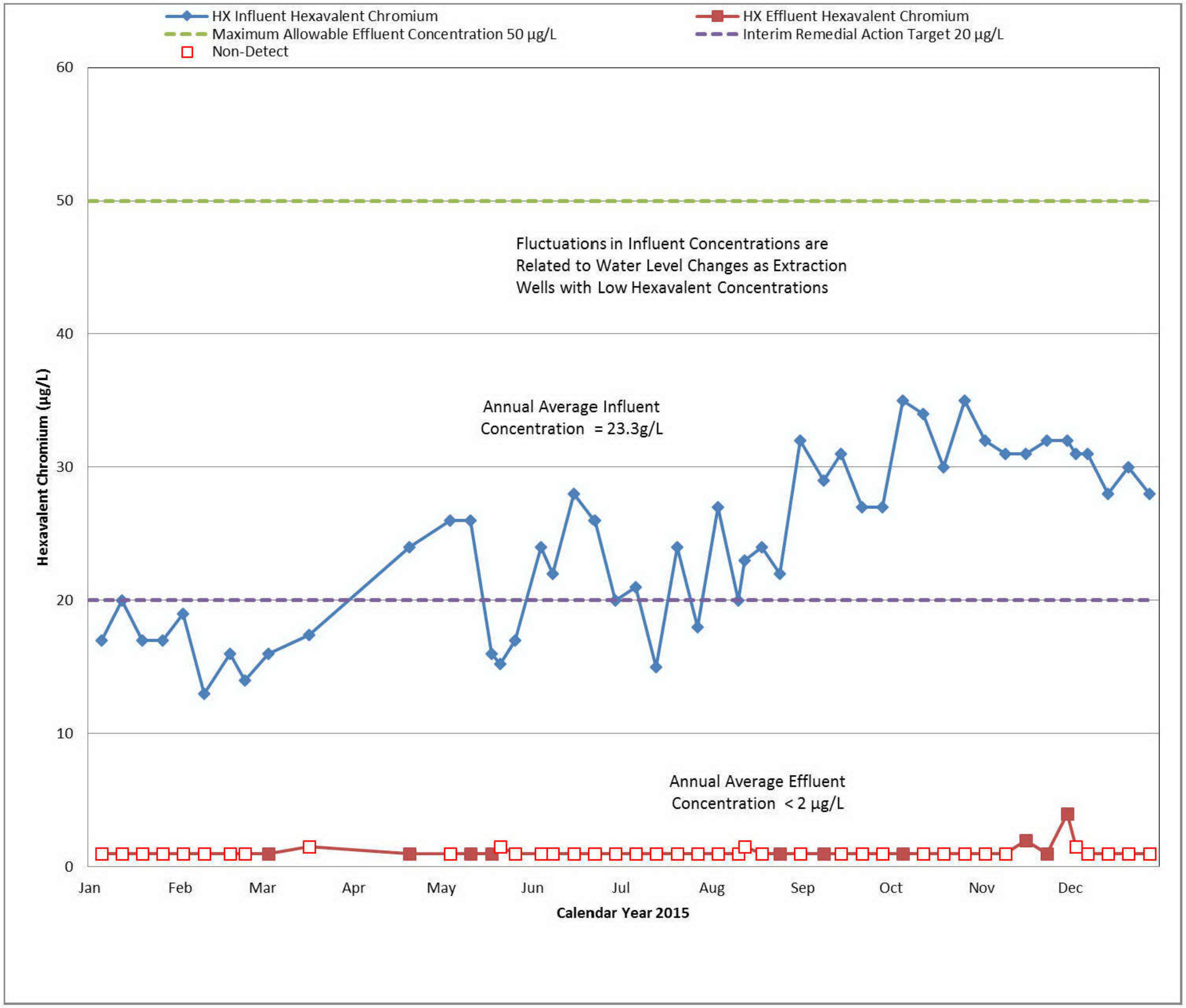


Figure 2-15. Influent/Effluent Concentrations for the HX P&T System

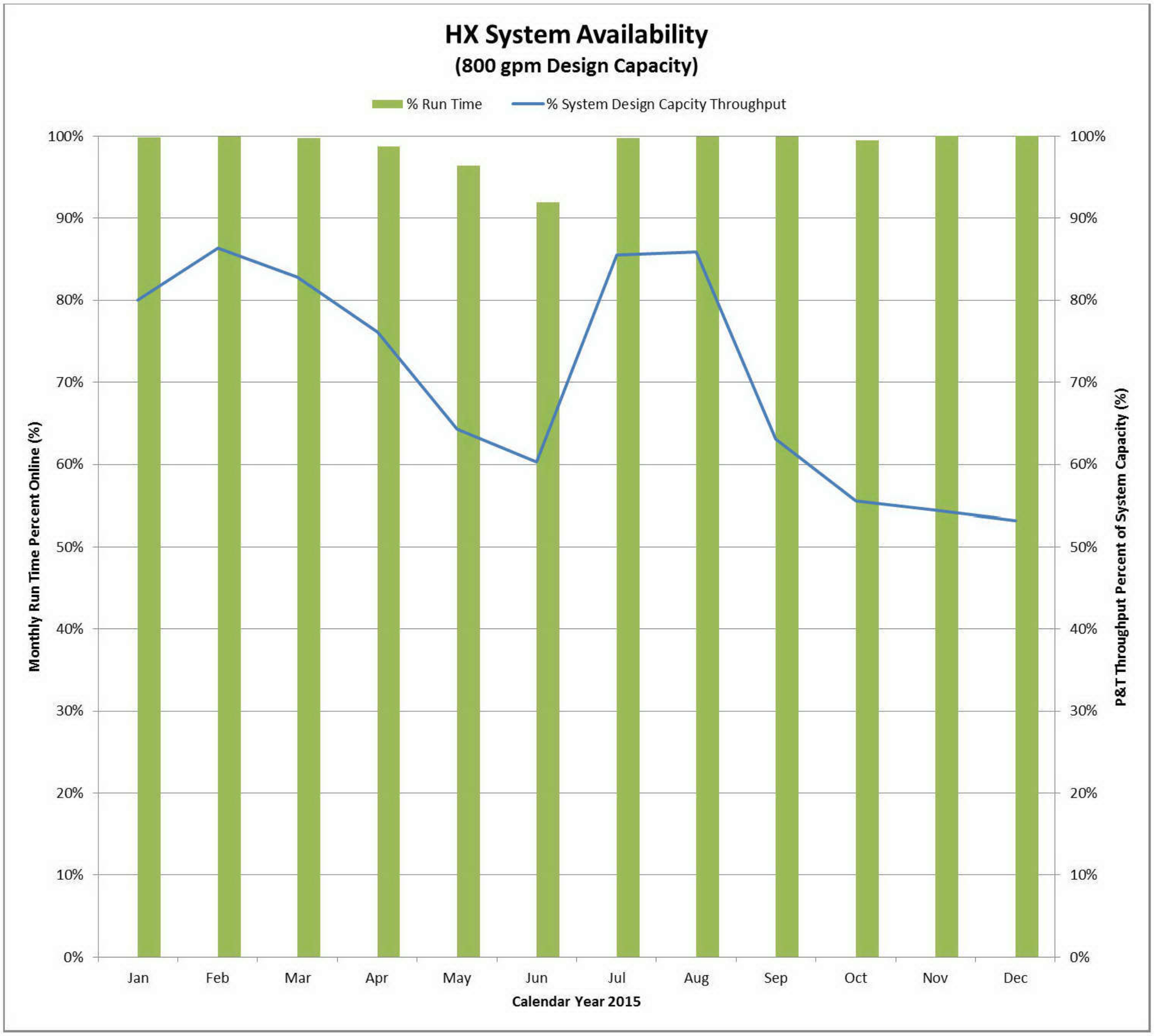


Figure 2-16. System Availability for the HX P&T System

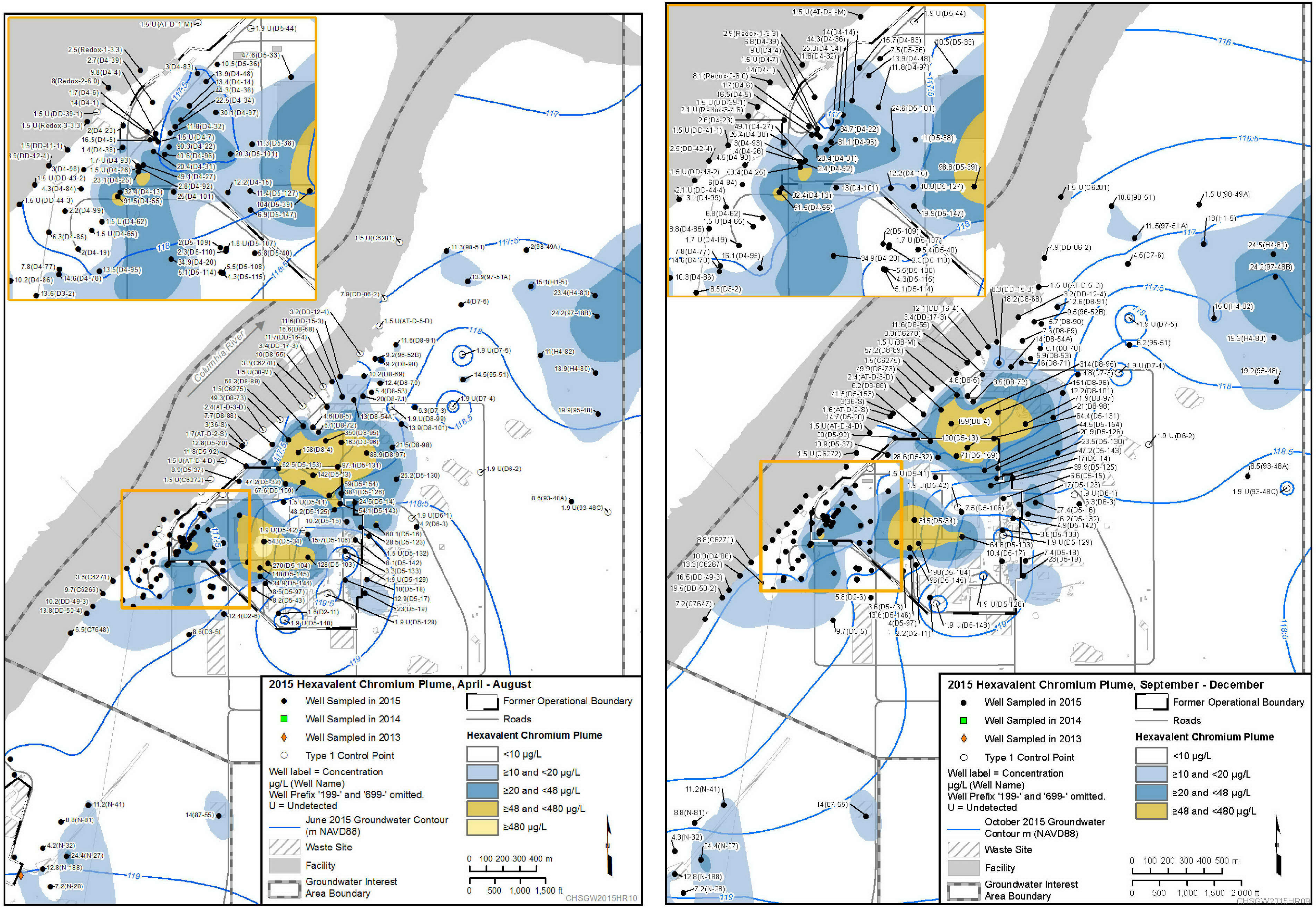


Figure 2-17. 100-HR-3 OU (100-D Area) Cr(VI) High River Stage to Low River Stage Comparison, 2015

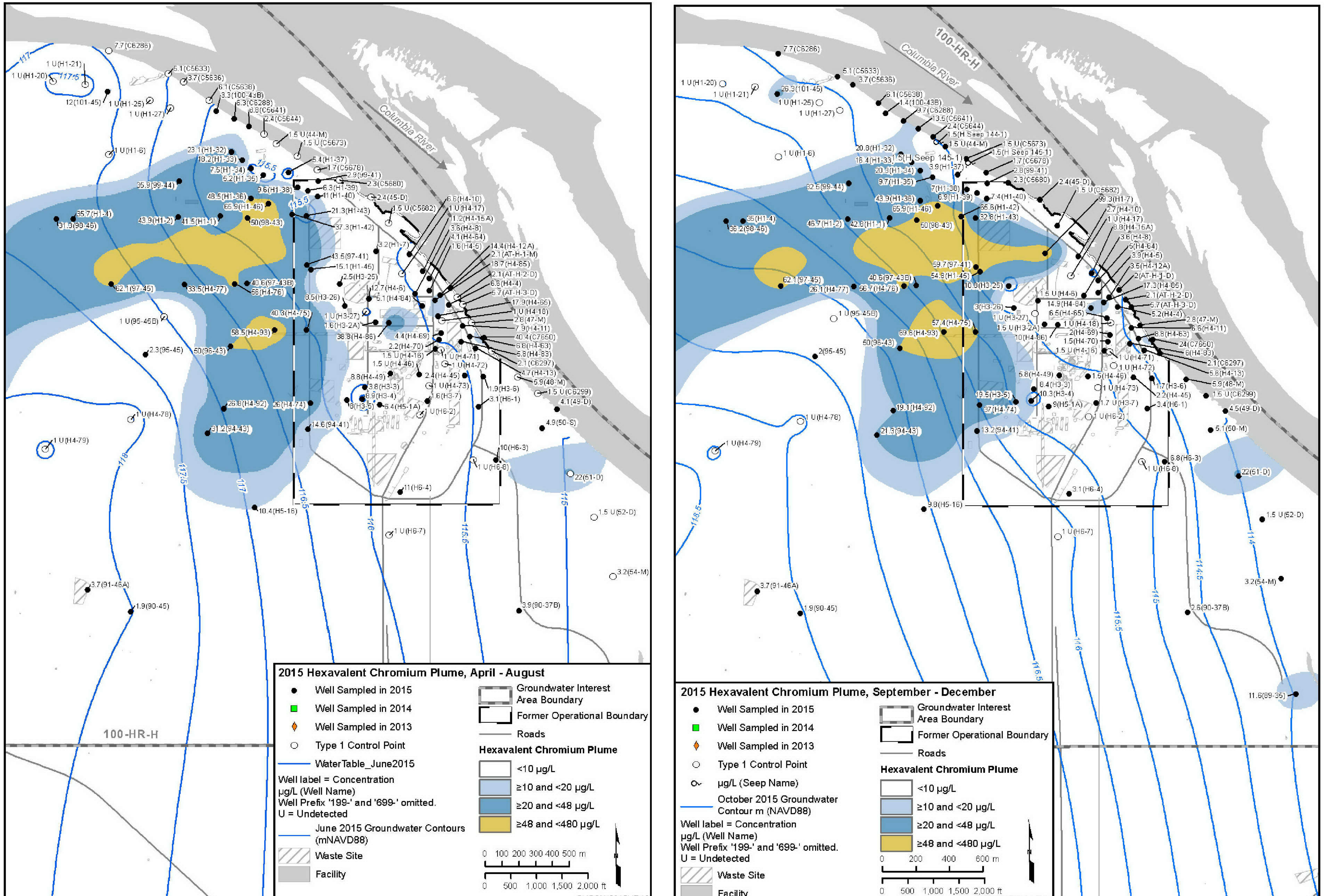


Figure 2-18. 100-HR-3 OU (100-H Area) Cr(VI) High River Stage to Low River Stage Comparison, 2015

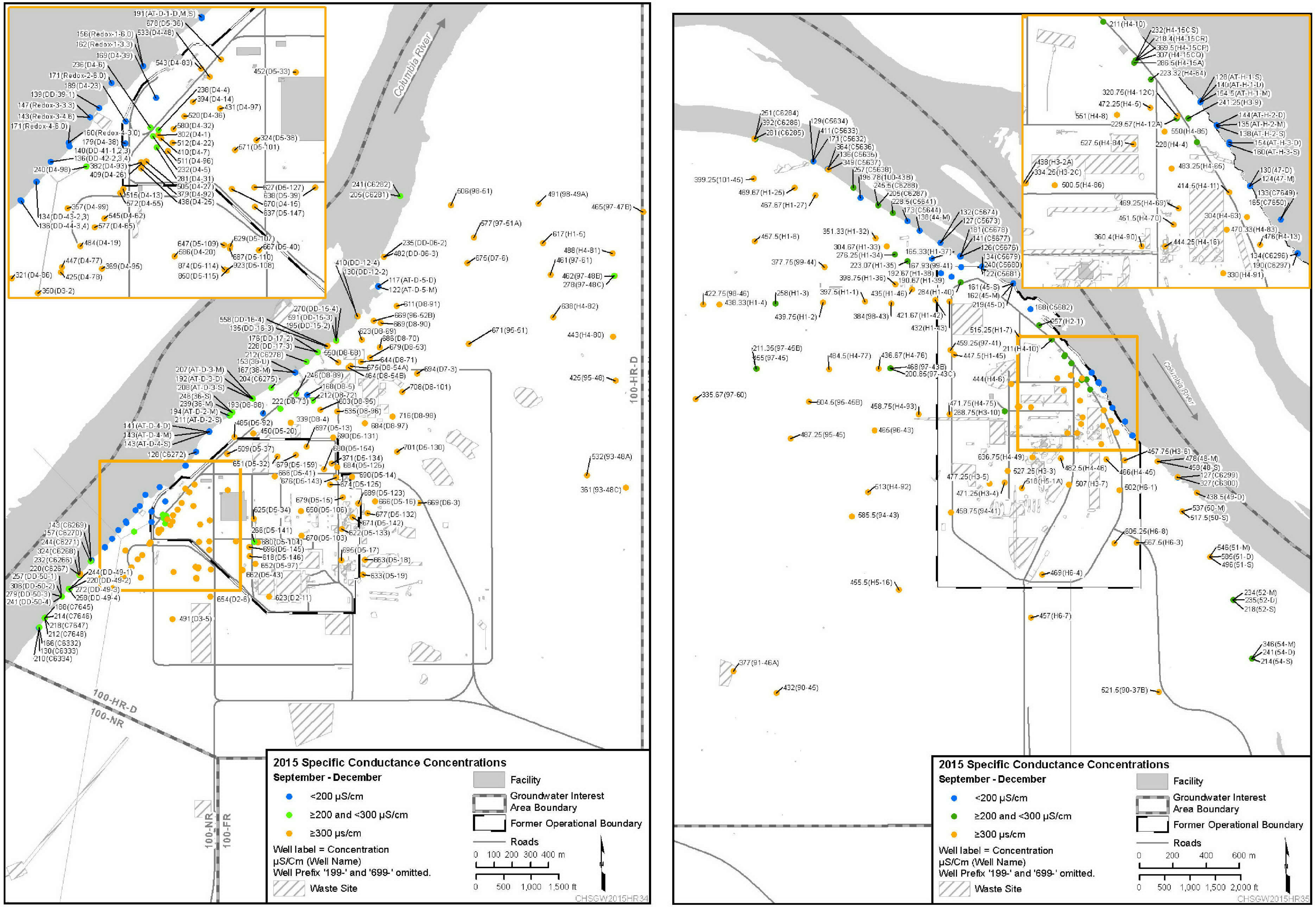


Figure 2-19. Specific Conductance at 100-HR-3 (Fall 2015)

This page intentionally left blank.

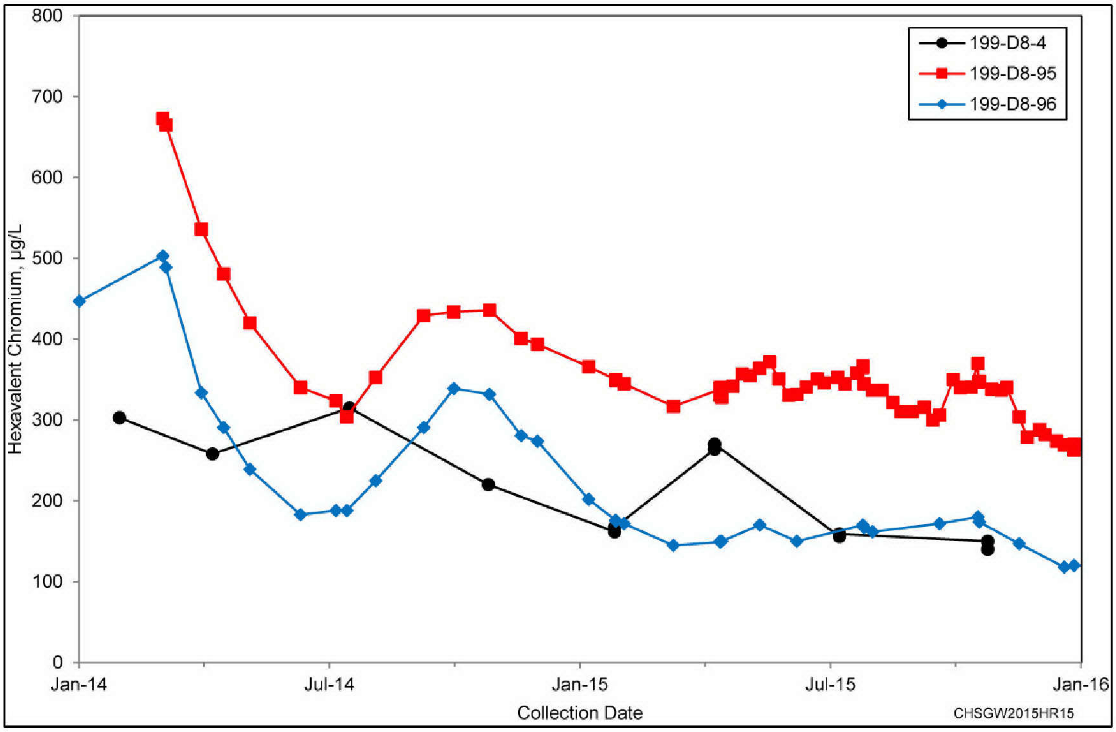


Figure 2-20. 100-HR Hexavalent Chromium Data for Wells 199-D8-95, 199-D8-96, and 199-D8-4

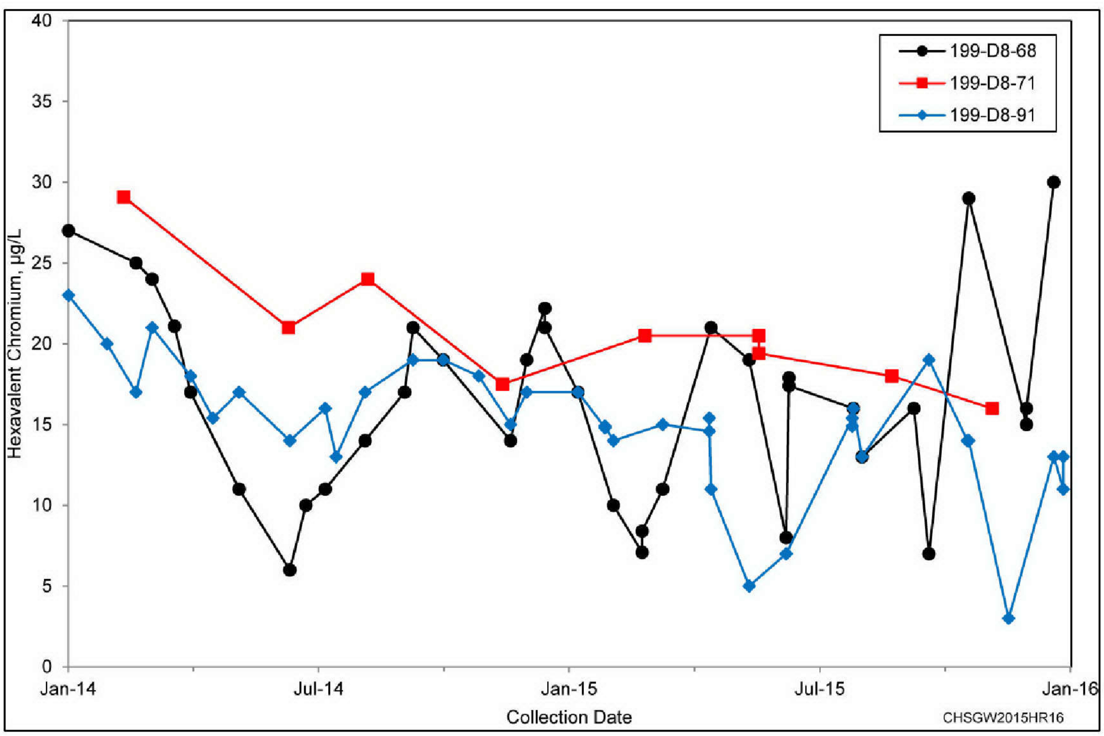


Figure 2-21. 100-HR Hexavalent Chromium Data for Wells 199-D8-68, 199-D8-71, and 199-D8-91

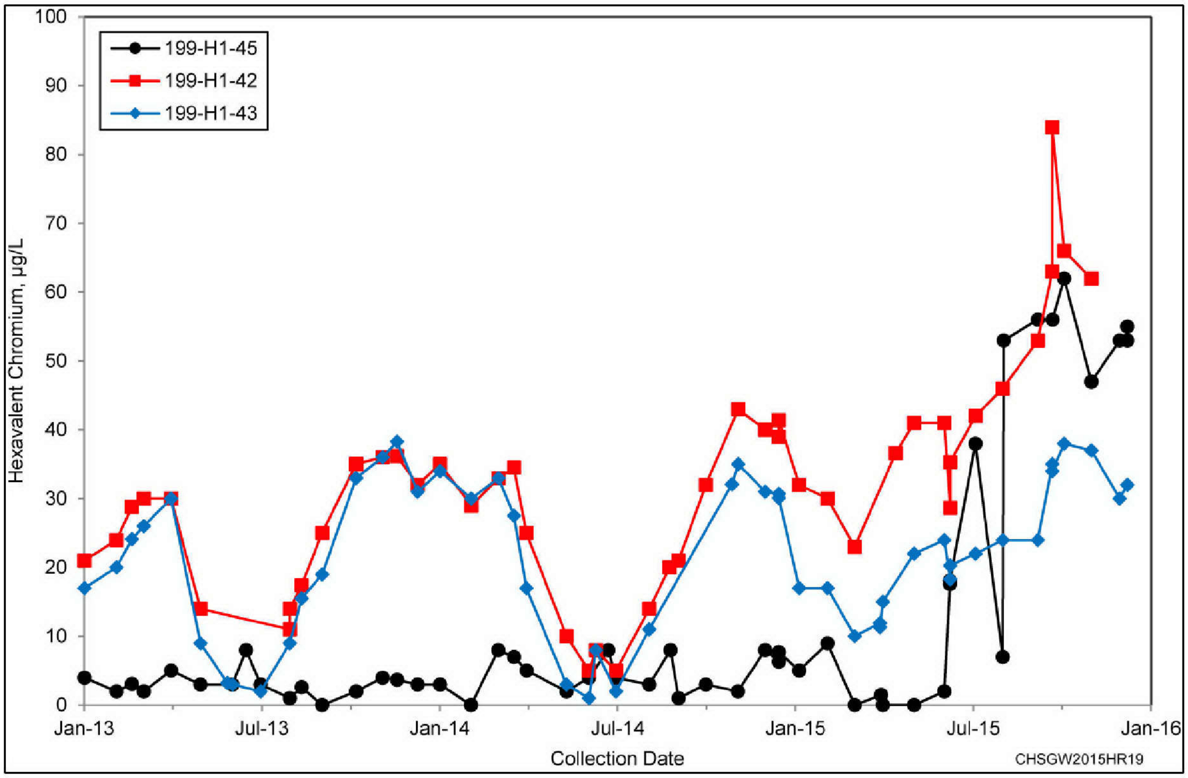


Figure 2-22. 100-HR Hexavalent Chromium Data for Wells 199-H1-45, 199-H1-42, and 199-H1-43

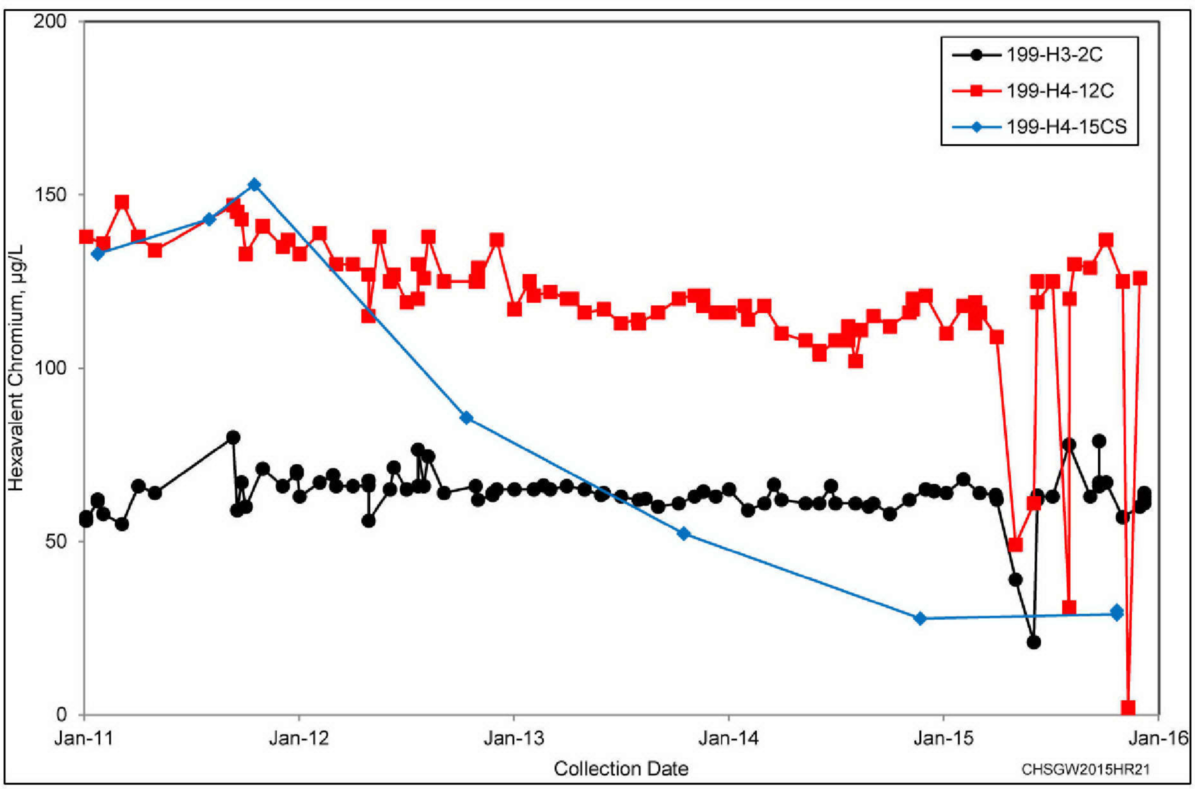


Figure 2-23. Trend Plot for Selected HX P&T System RUM Extraction Wells

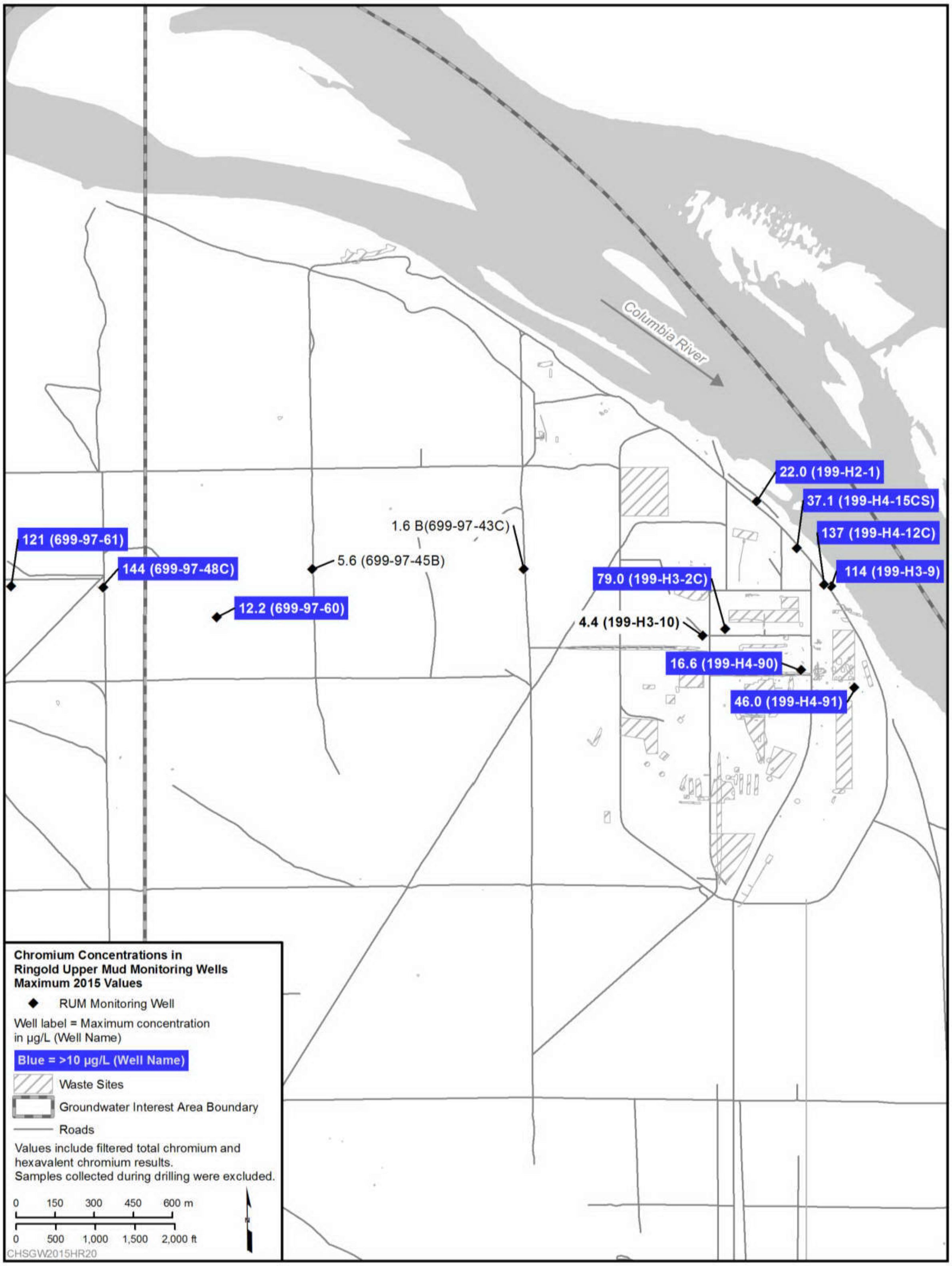


Figure 2-24. 100-H Area and Horn: Cr(VI) in the First Water-Bearing Unit of the RUM, 2015

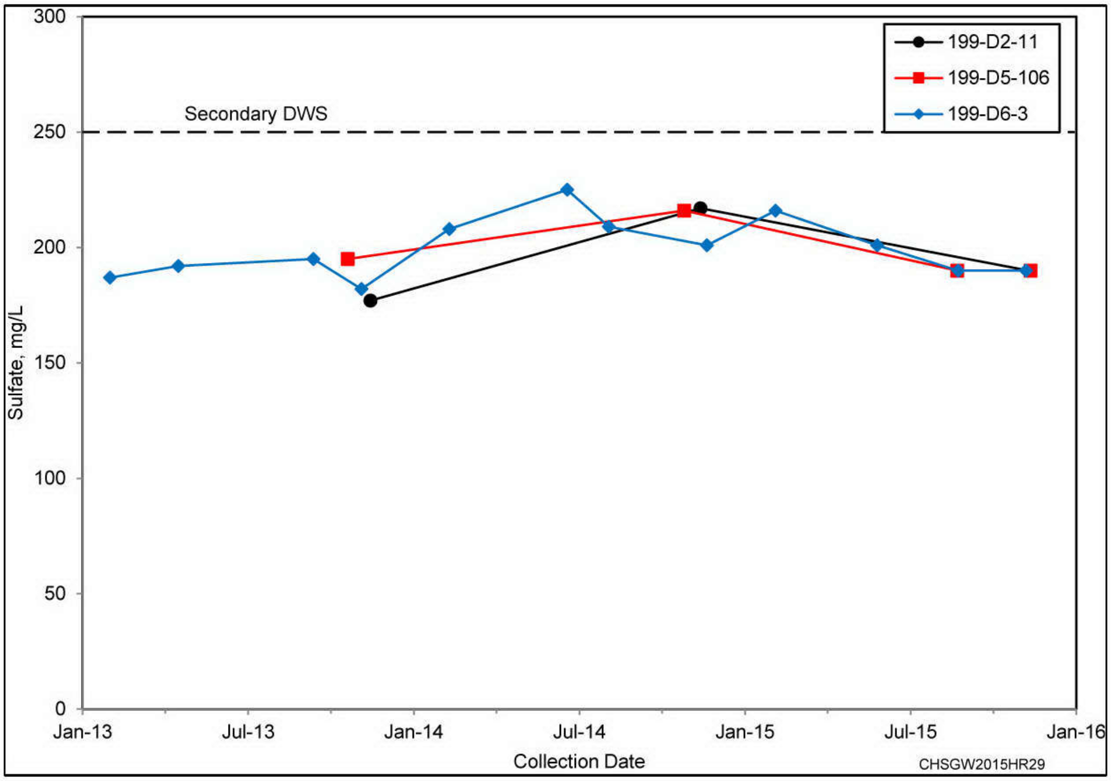


Figure 2-25. 100-D Sulfate Data for Wells 199-D2-11, 199-D5-106, and 199-D6-3

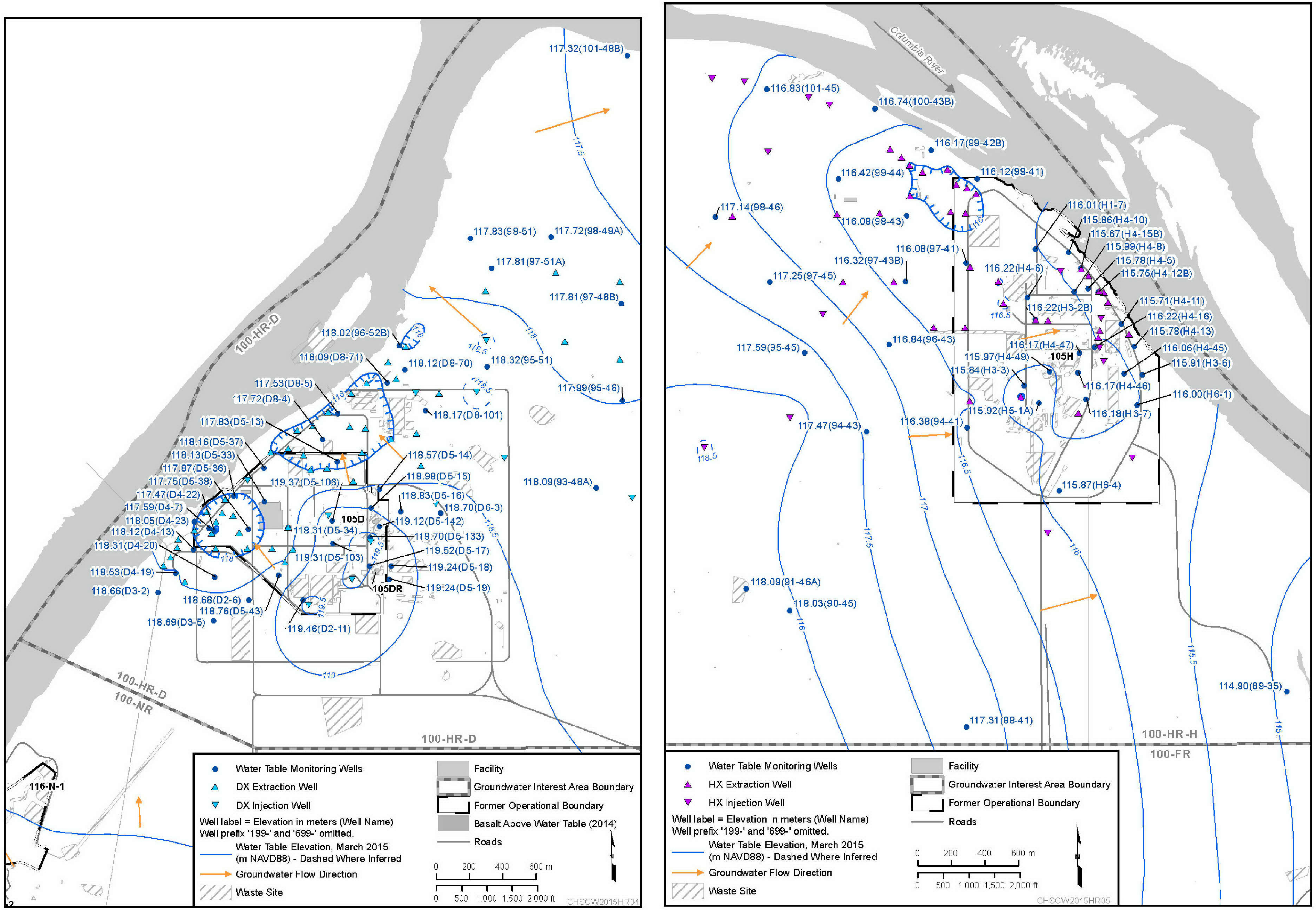


Figure 2-26. 100-HR-3 OU Water Table Elevation Map, March 2015

This page intentionally left blank.

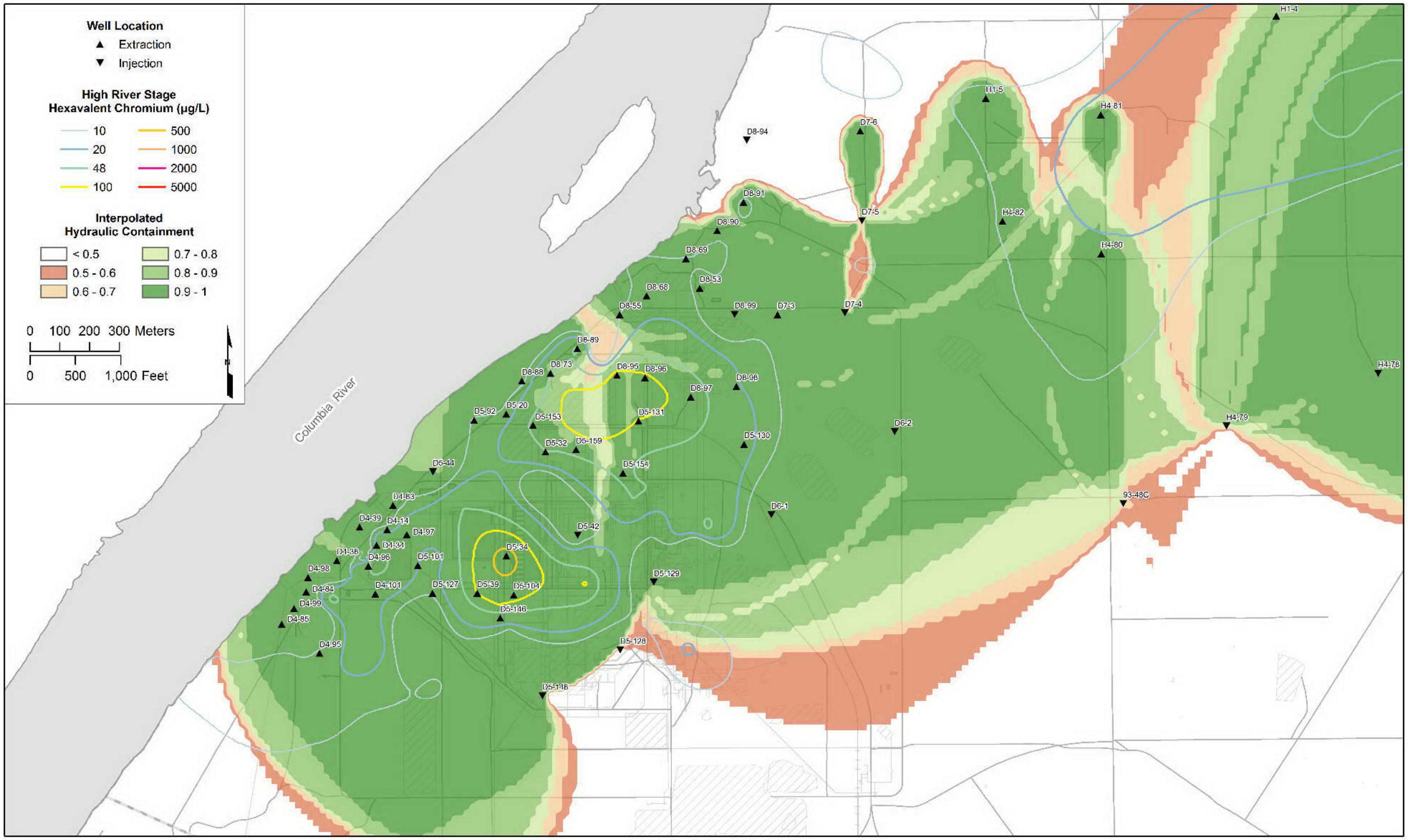


Figure 2-27(a). 100-D Area Interpolated CFM and High River Stage Chromium Contamination

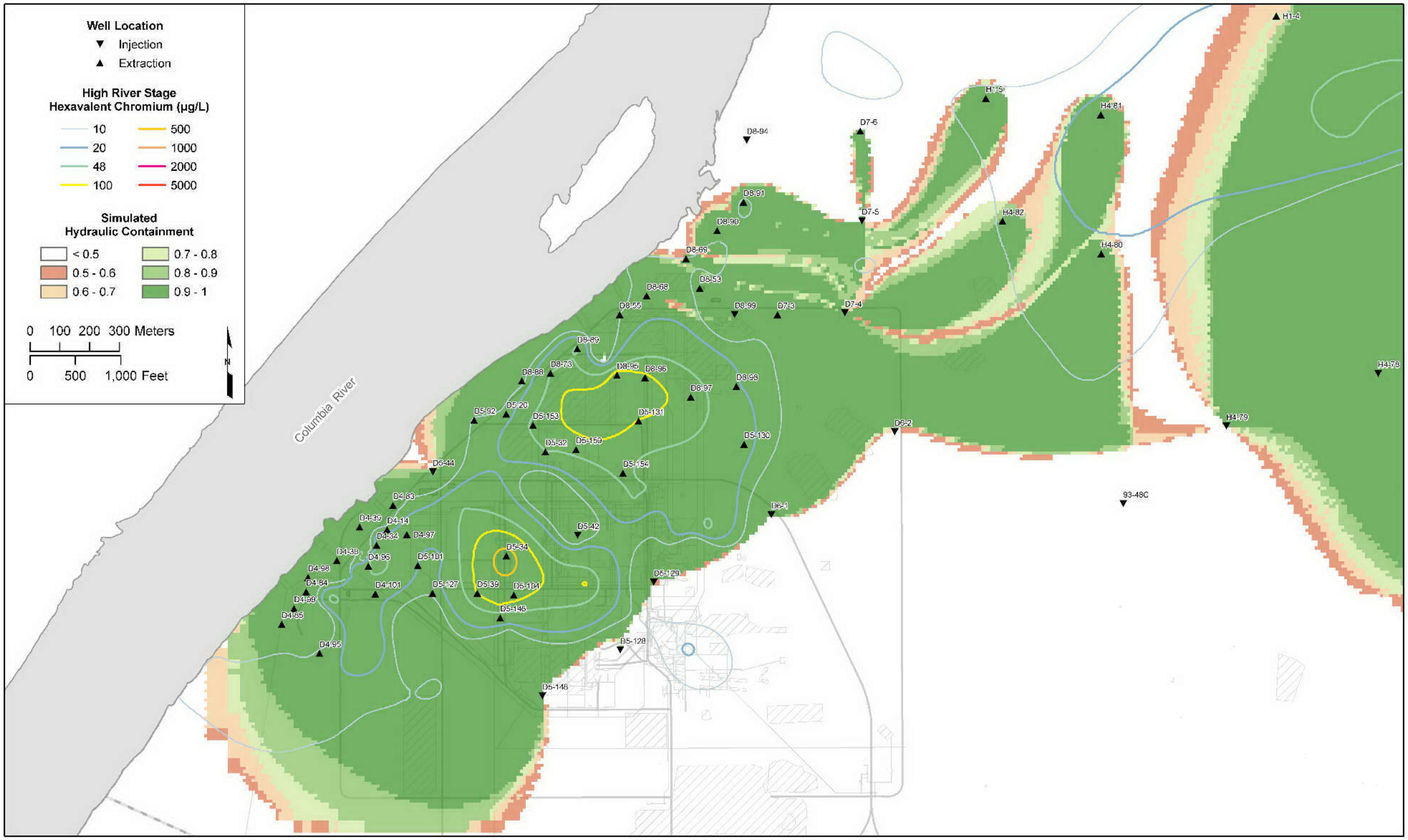


Figure 2-27(b). 100-D Area Simulated CFM and High River Stage Chromium Contamination

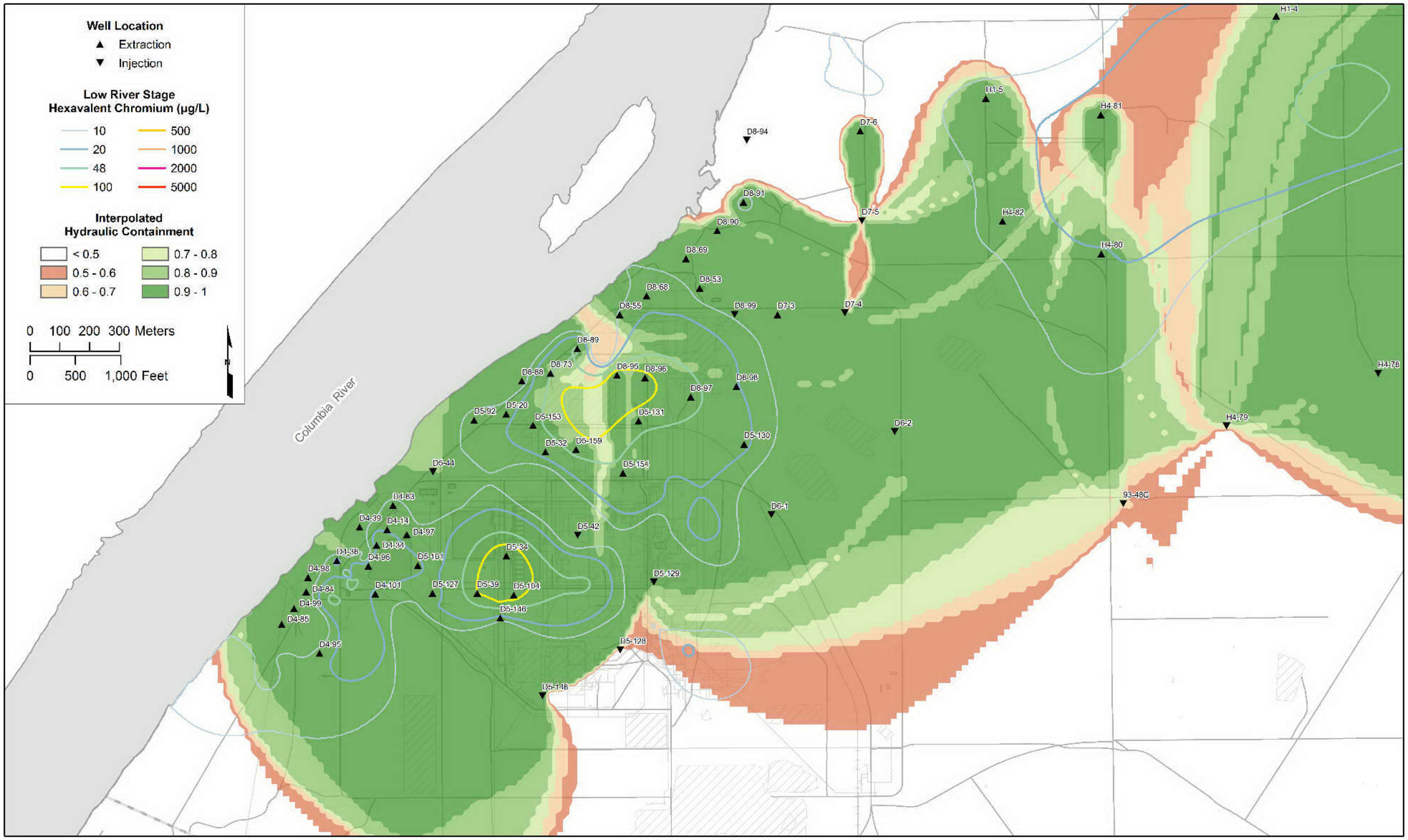


Figure 2-27(c). 100-D Area Interpolated CFM and Low River Stage Chromium Contamination

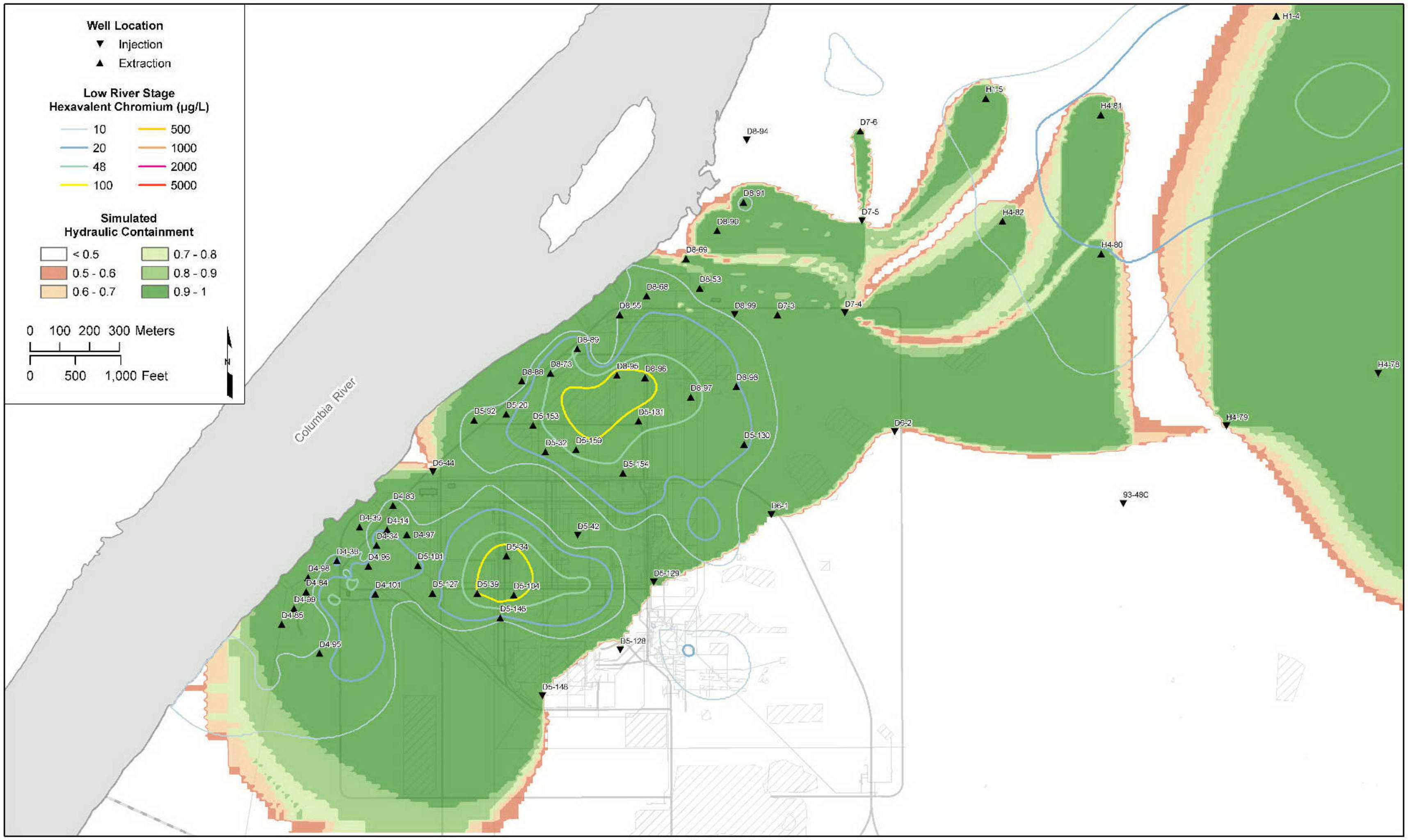


Figure 2-27(d). 100-D Area Simulated CFM and Low River Stage Chromium Contamination

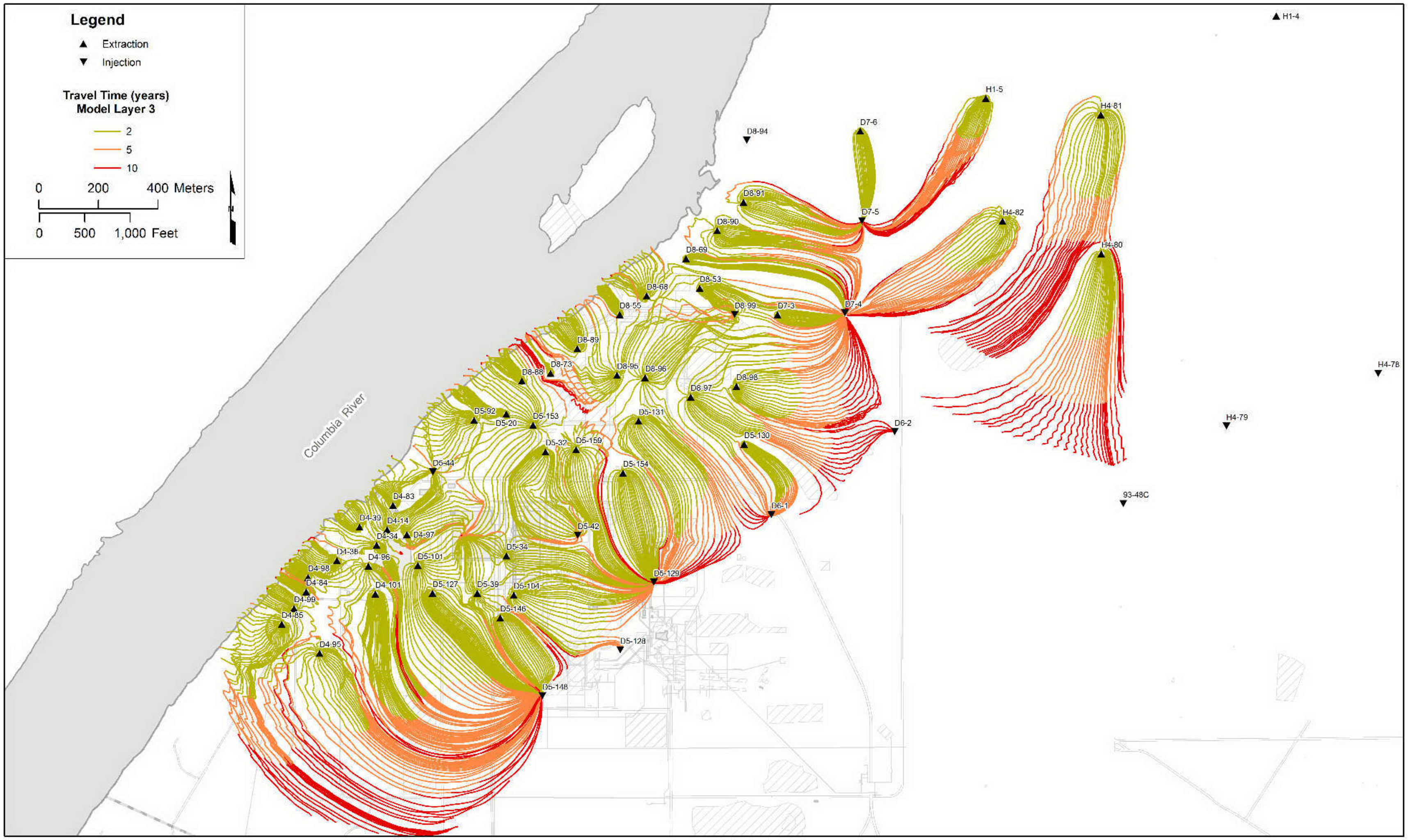


Figure 2-27(e). 100-D Area Groundwater Flow Lines of Capture Zone Flow Field, 2015

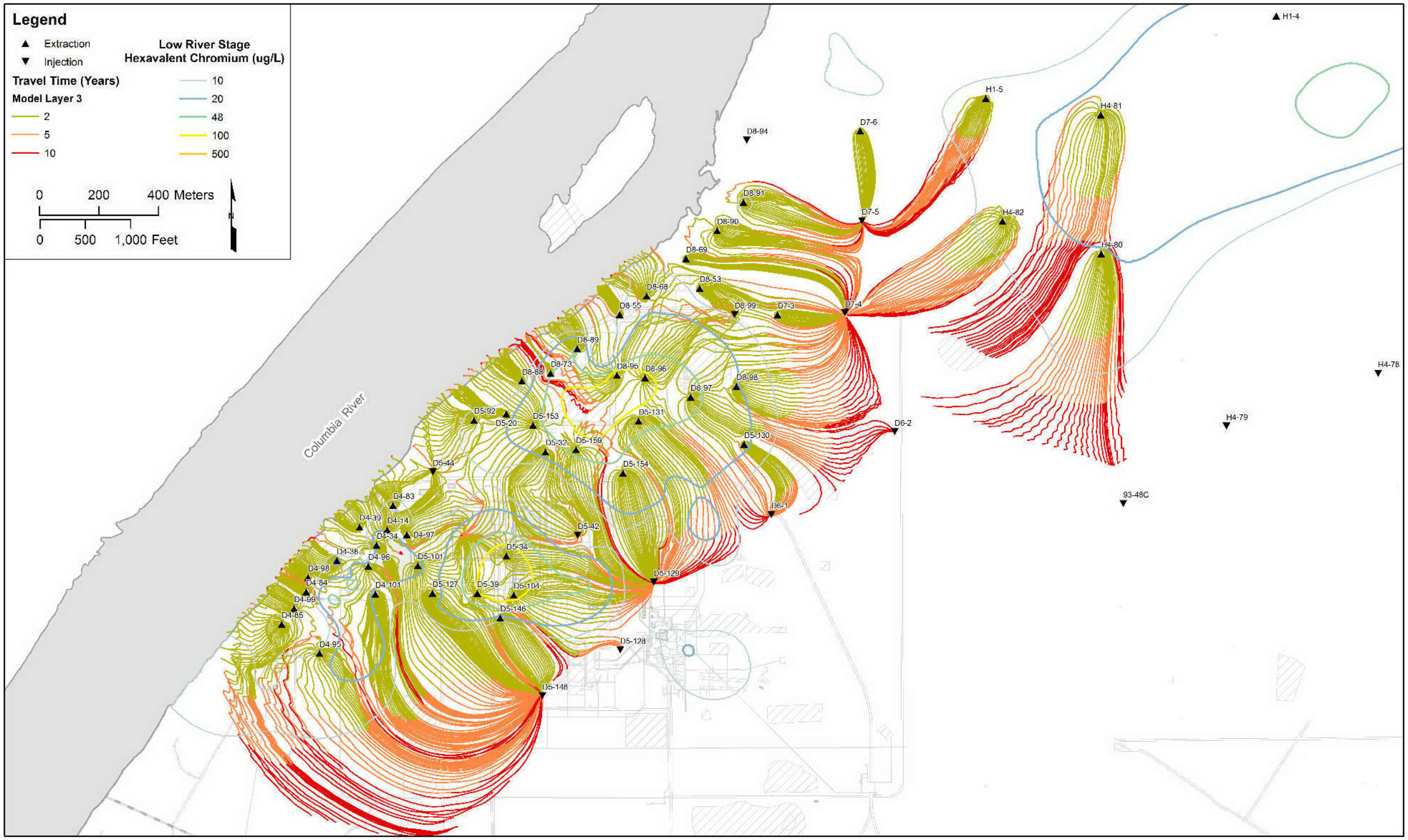


Figure 2-27(f). 100-D Area Groundwater Flow Lines of Capture Zone Overlay with Low River Stage Chromium Plume Contours

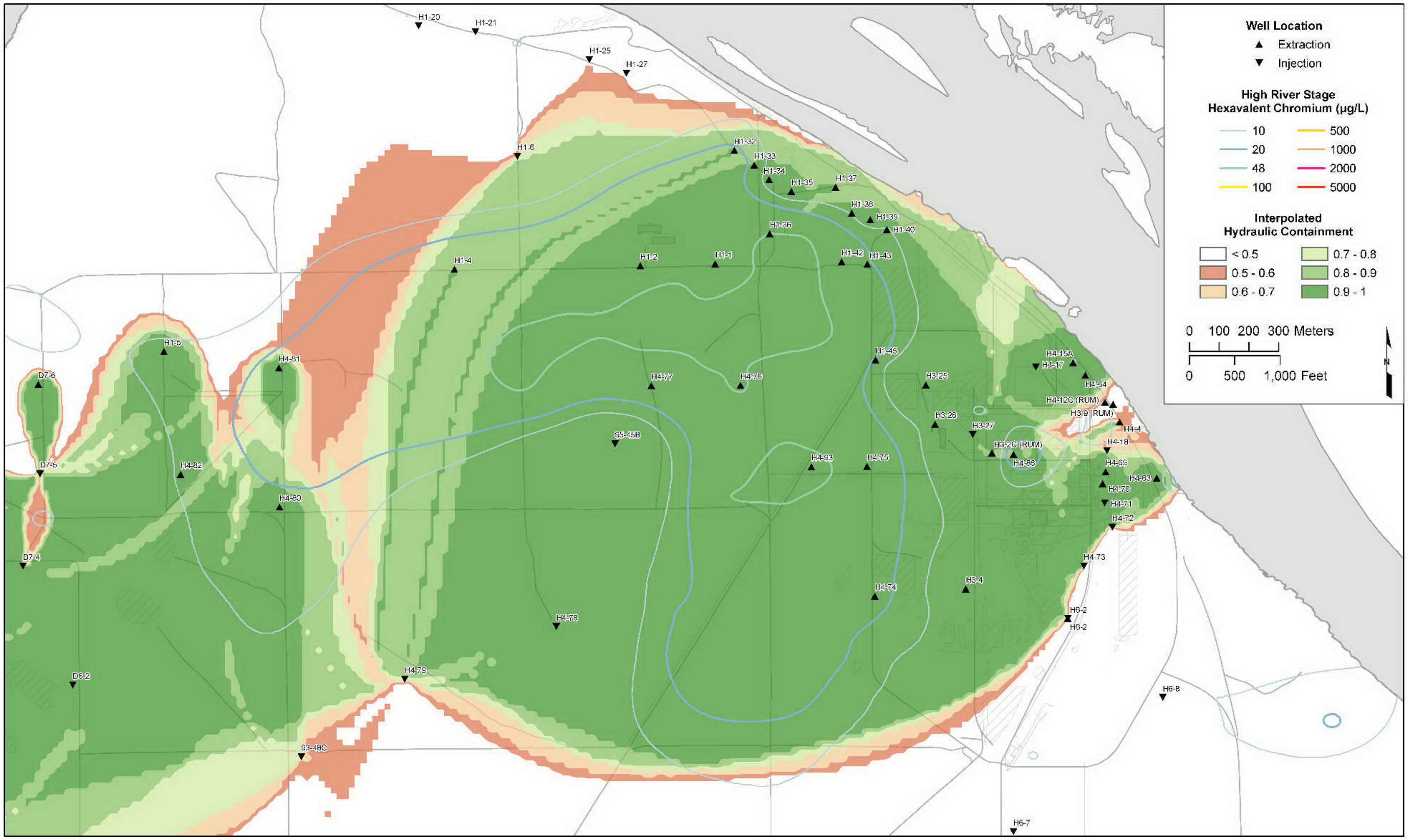


Figure 2-28(a). 100-H Area Interpolated CFM and High River Stage Chromium Contamination

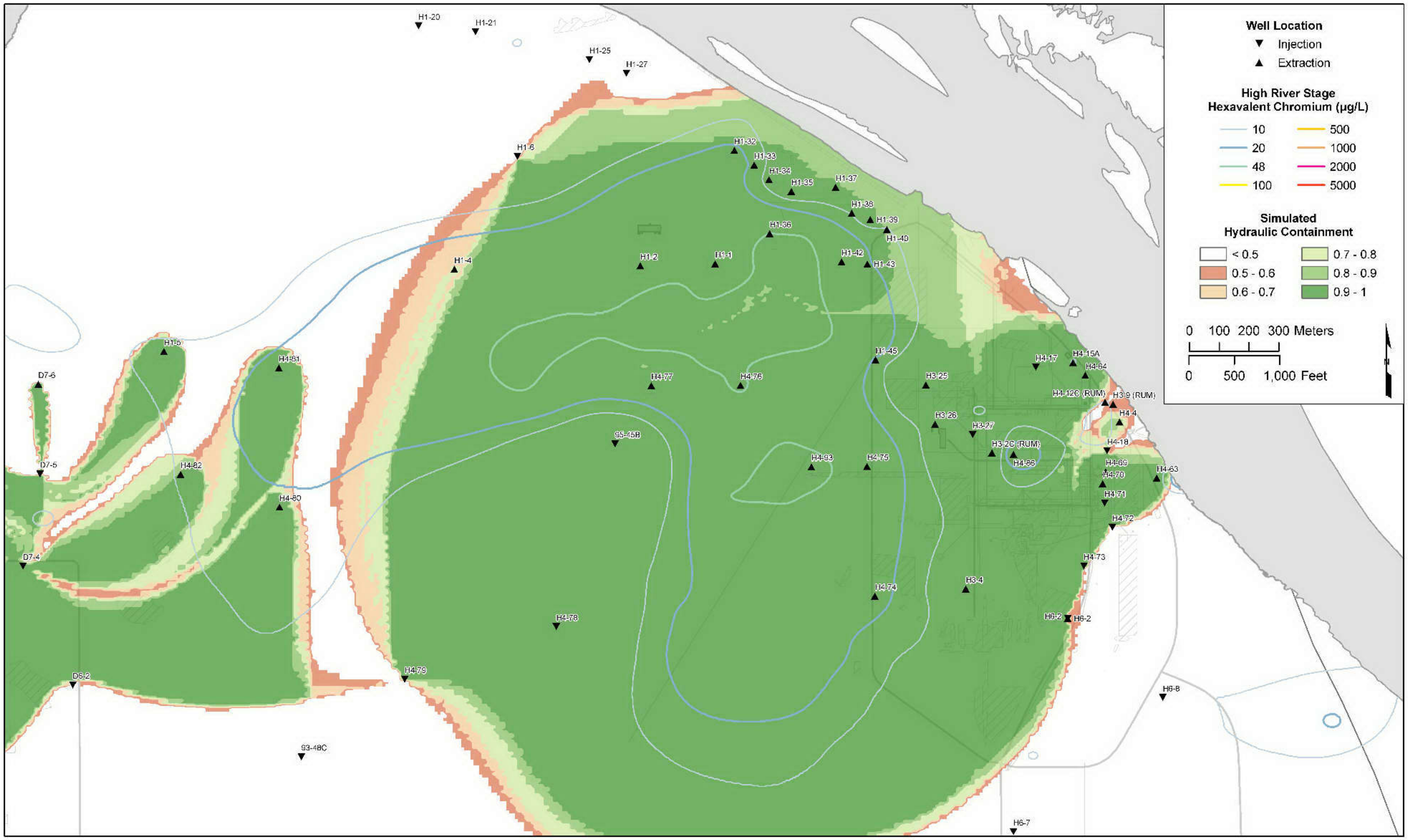


Figure 2-28(b). 100-H Area Simulated CFM and High River Stage Chromium Contamination

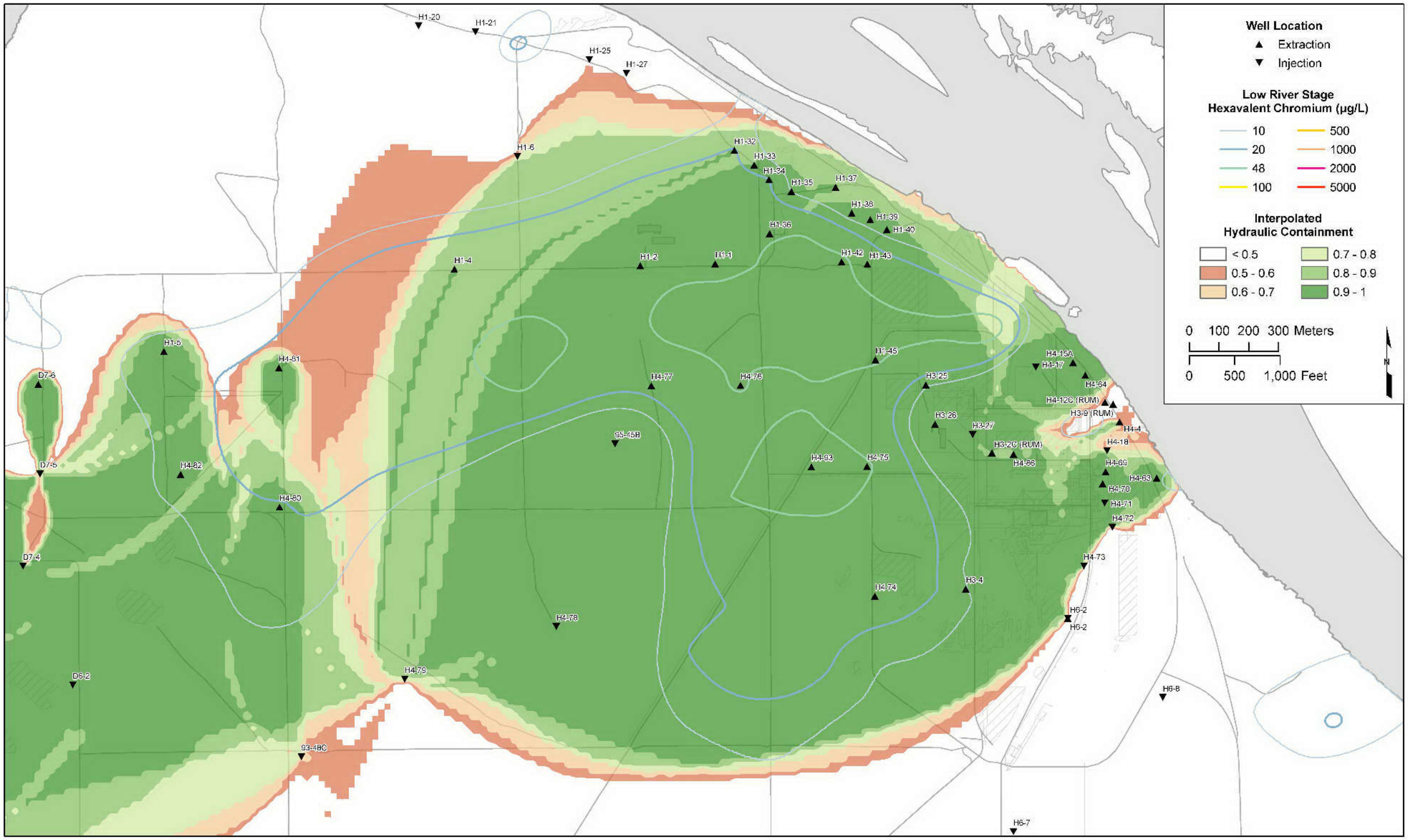


Figure 2-28(c). 100-H Area Interpolated CFM and Low River Stage Chromium Contamination

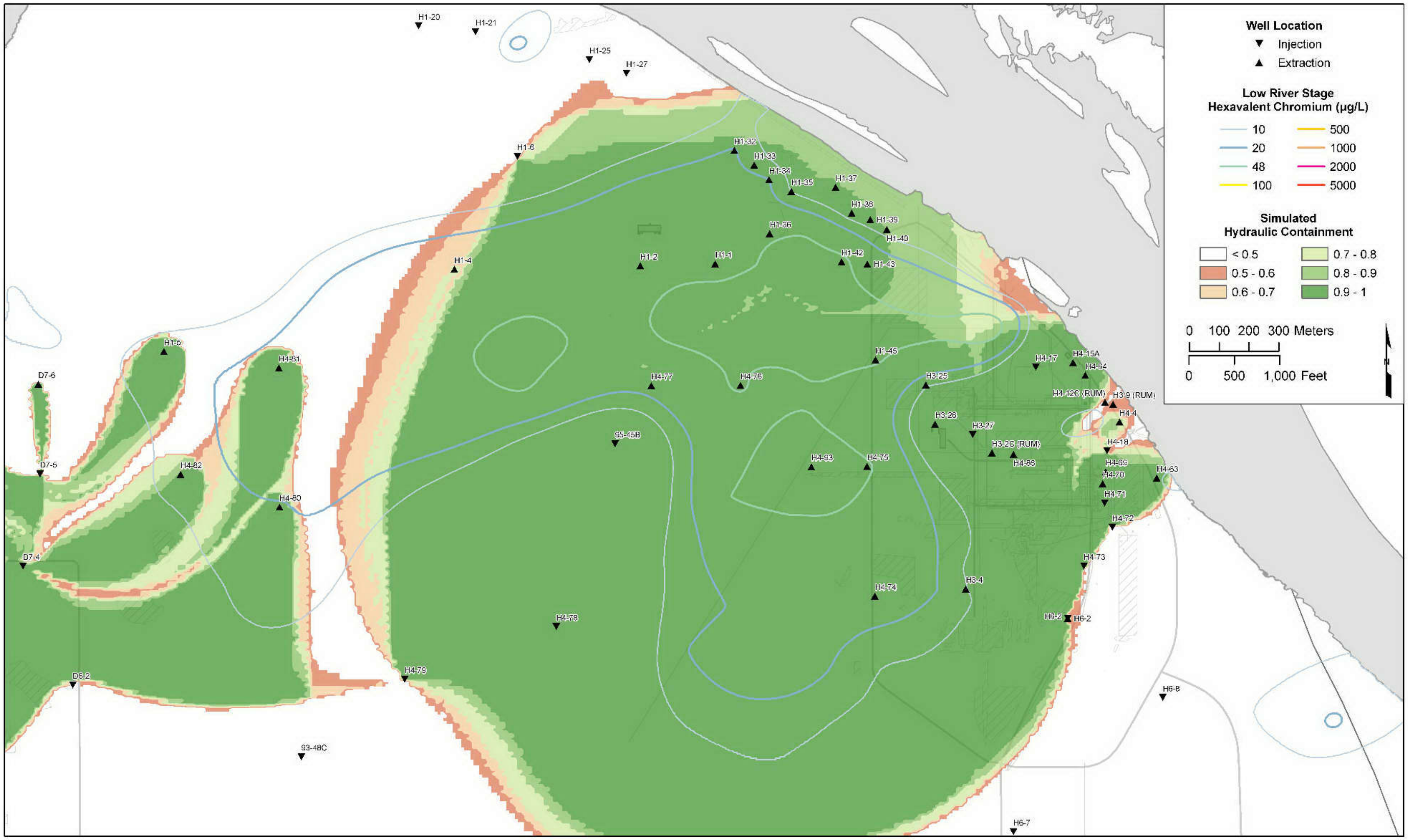


Figure 2-28(d). 100-H Area Simulated CFM and Low River Stage Chromium Contamination

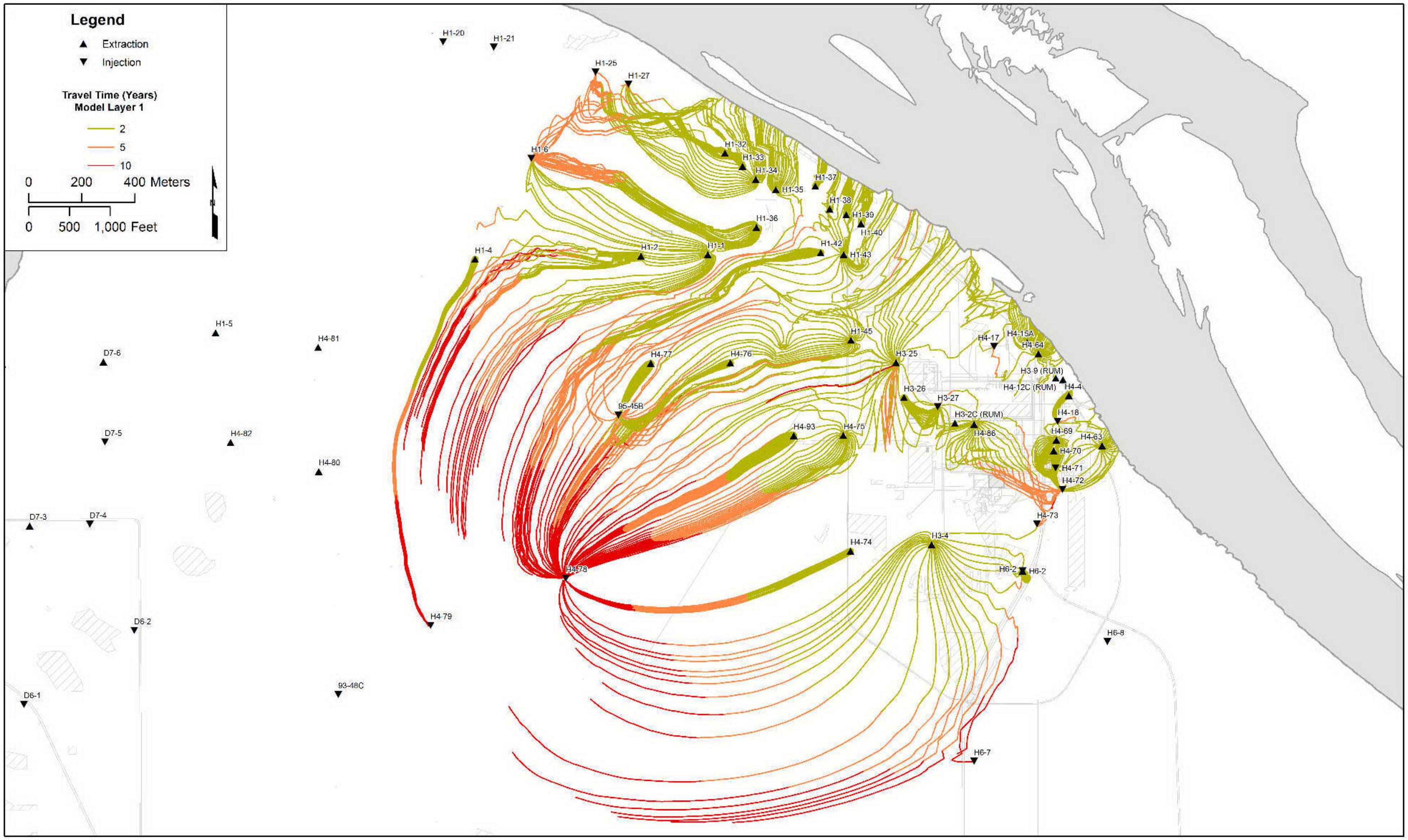


Figure 2-28(e). 100-H Area Groundwater Flow Lines of Capture Zone Flow Field, 2015

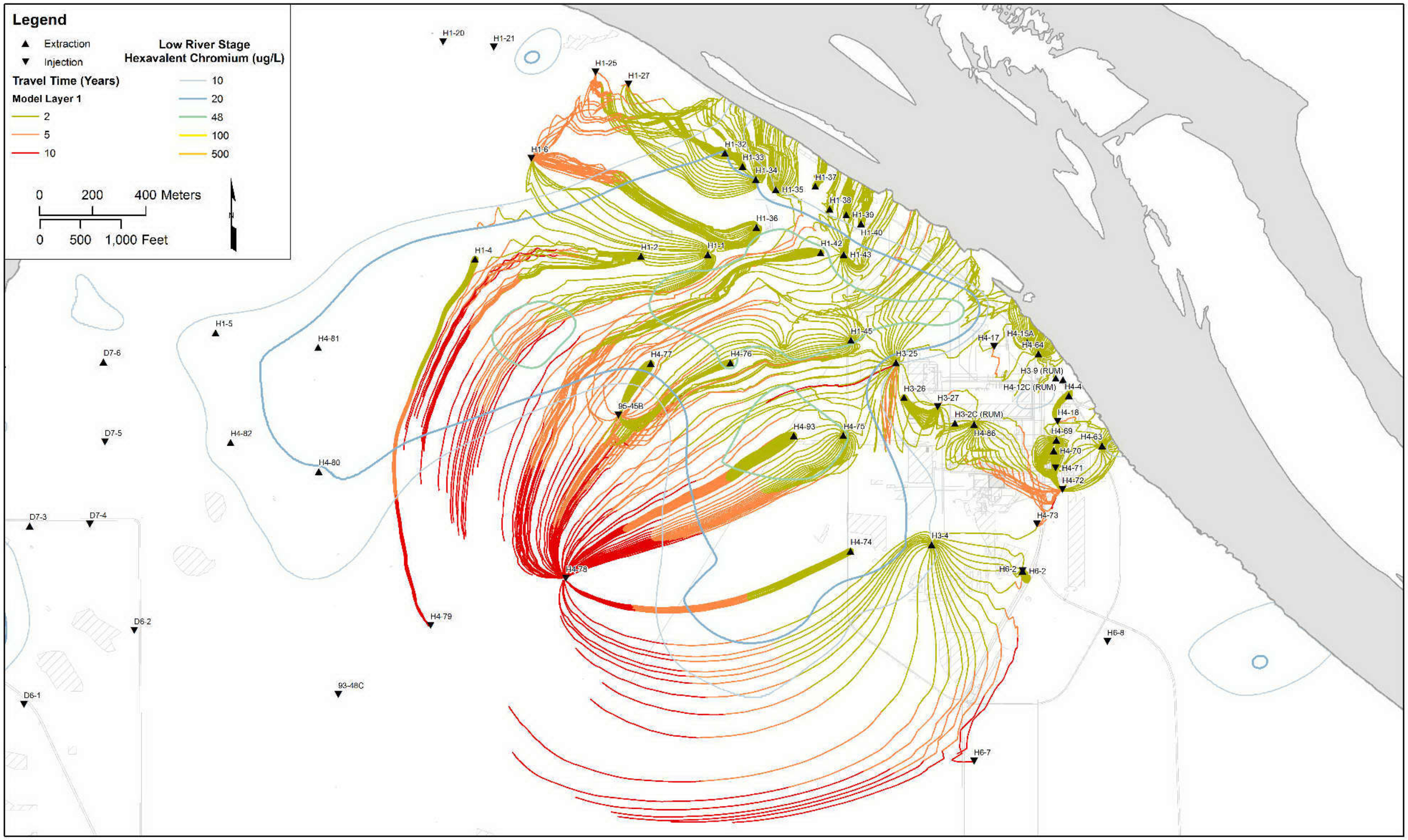


Figure 2-28(f). 100-H Area Groundwater Flow Lines of Capture Zone Overlay with Low River Stage Chromium Plume Contours

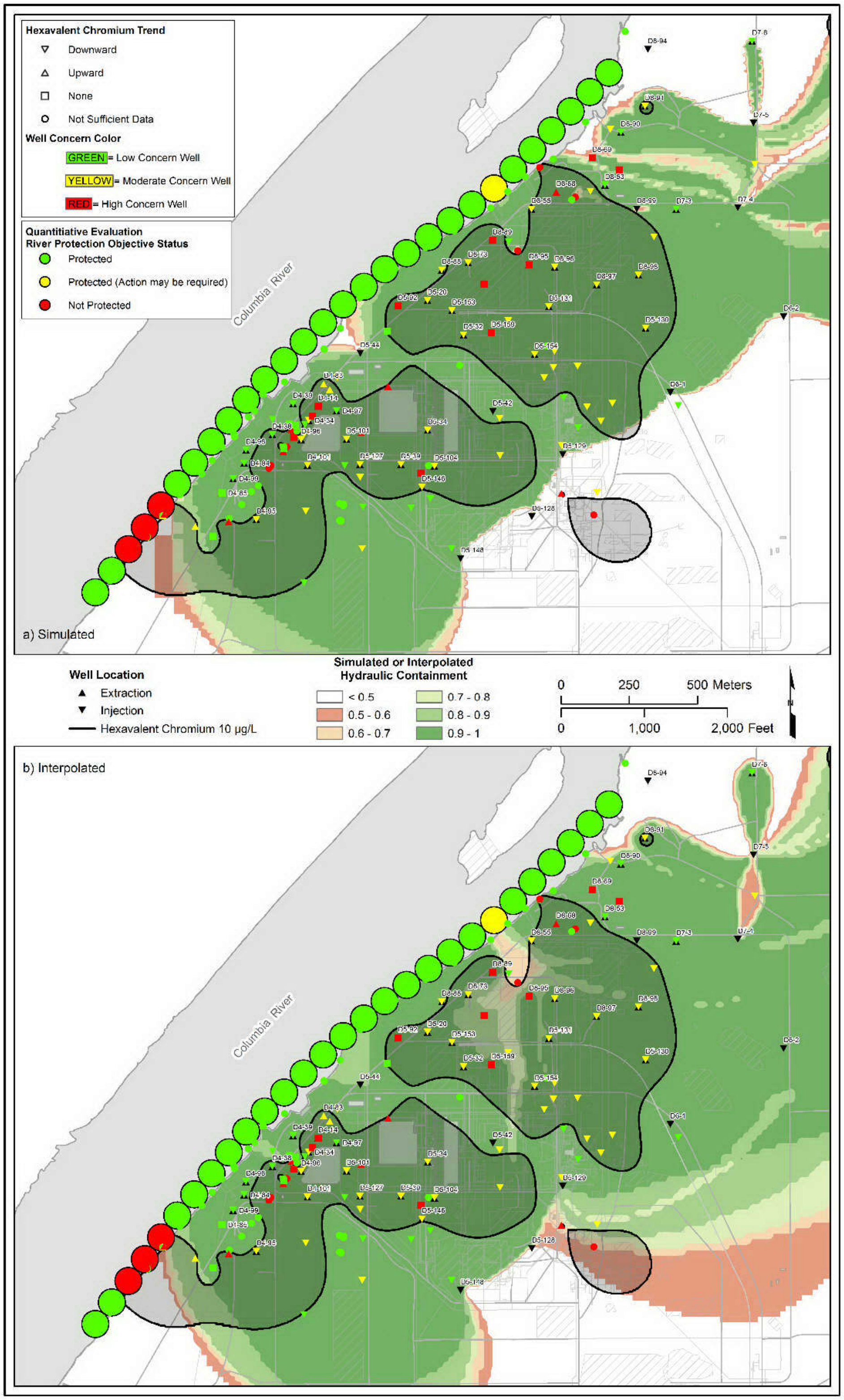


Figure 2-29(a). 100-D Area Quantitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

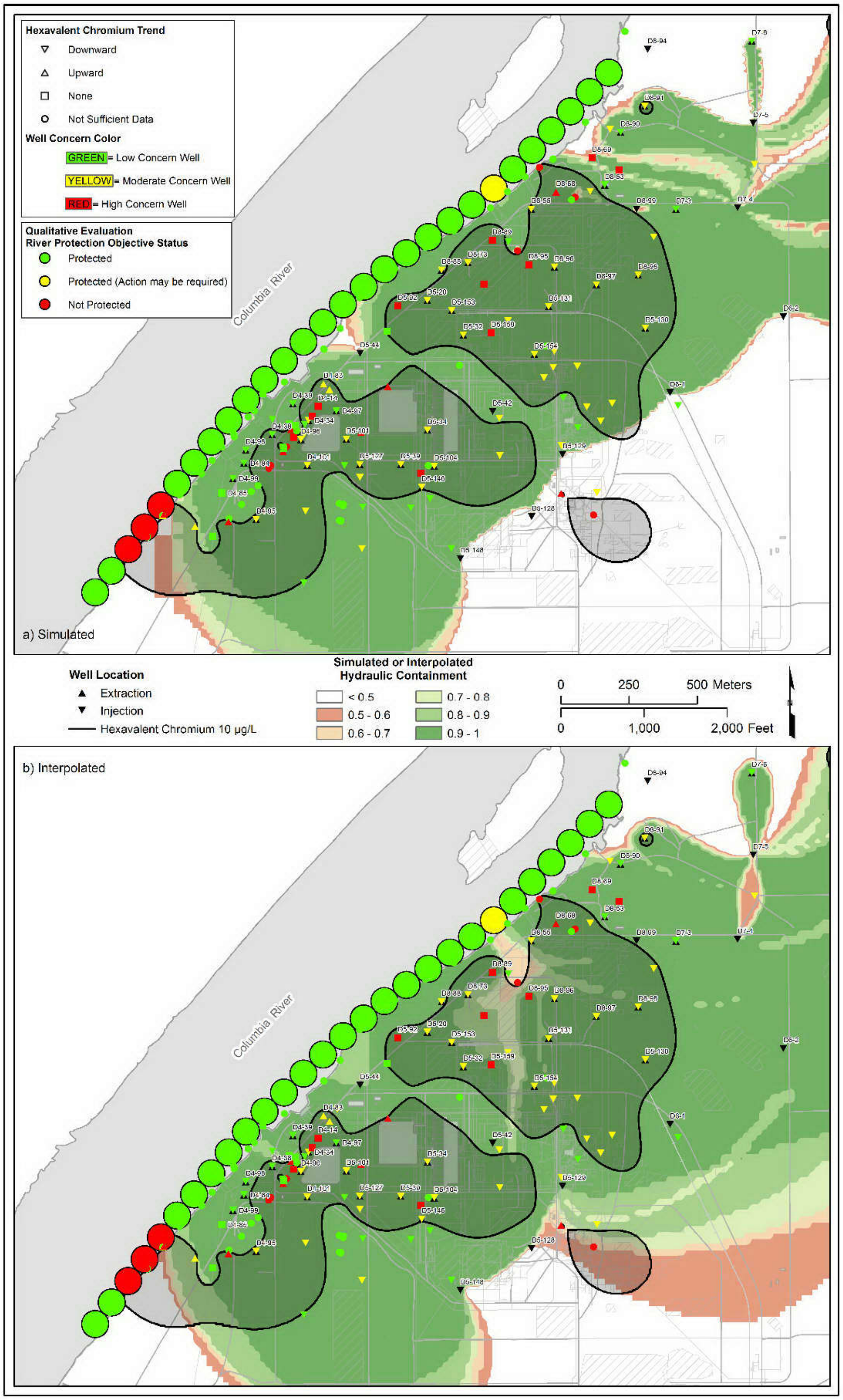


Figure 2-29(b). 100-D Area Qualitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

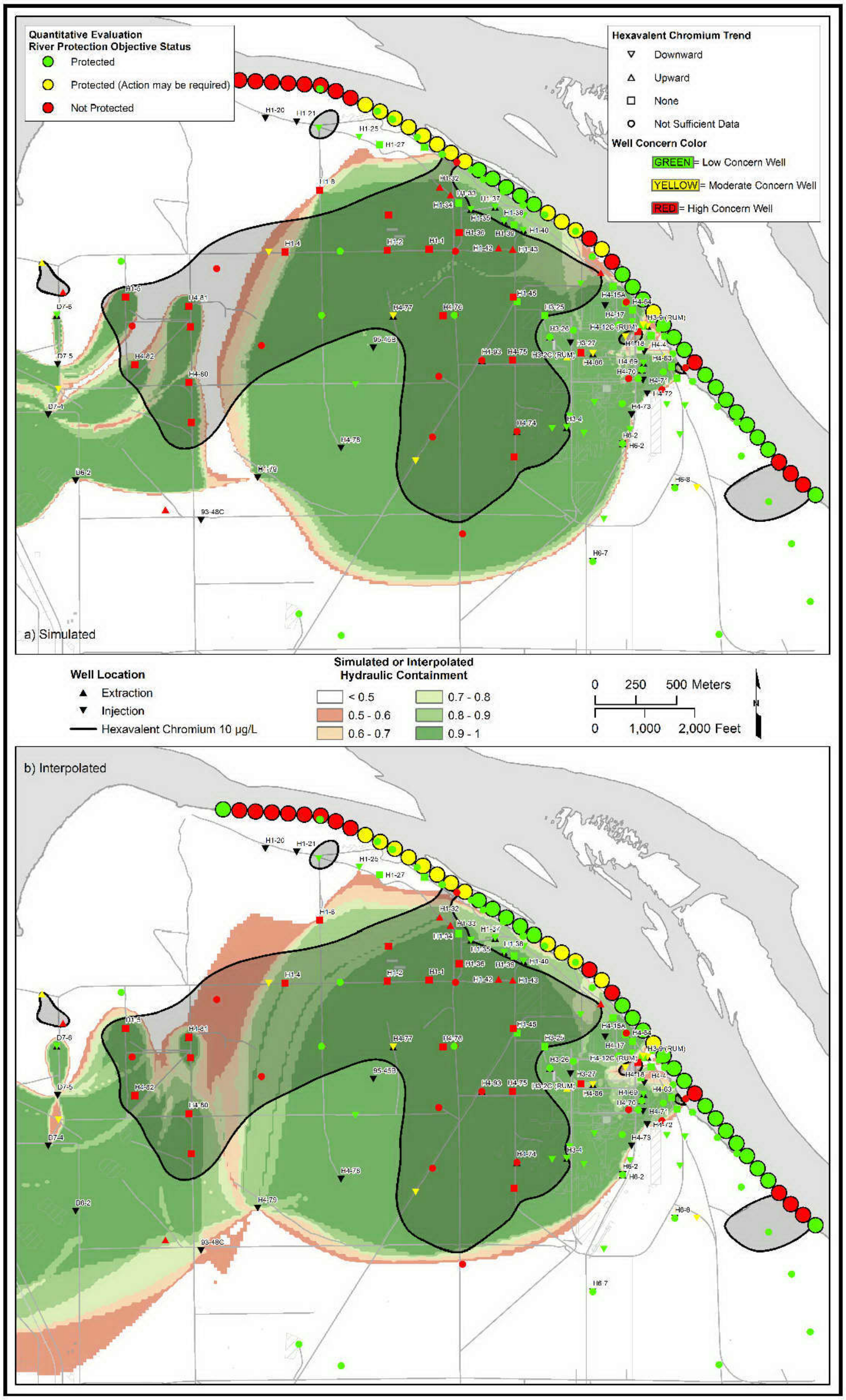


Figure 2-30(a). 100-H Area Quantitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

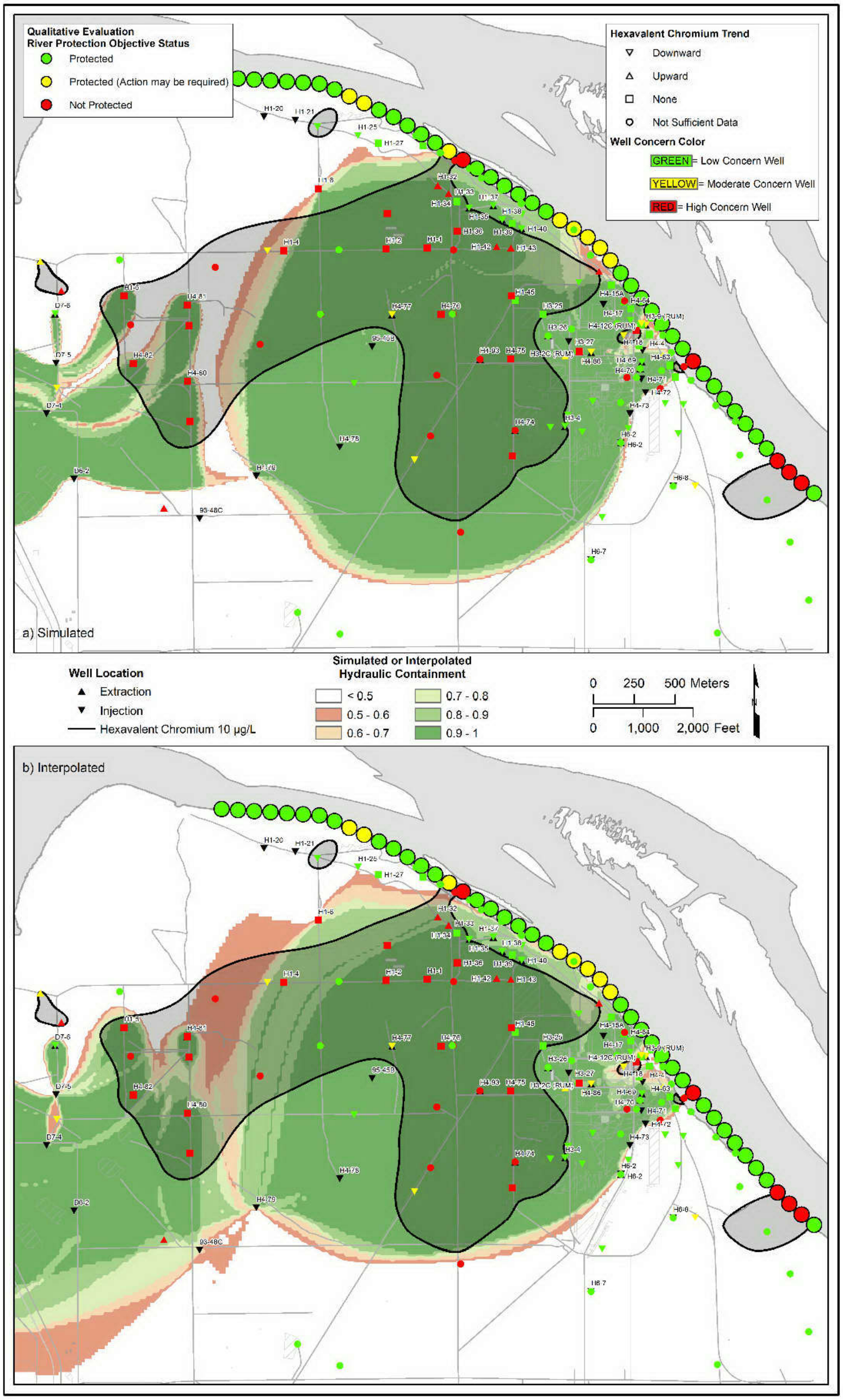


Figure 2-30(b). 100-H Area Qualitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

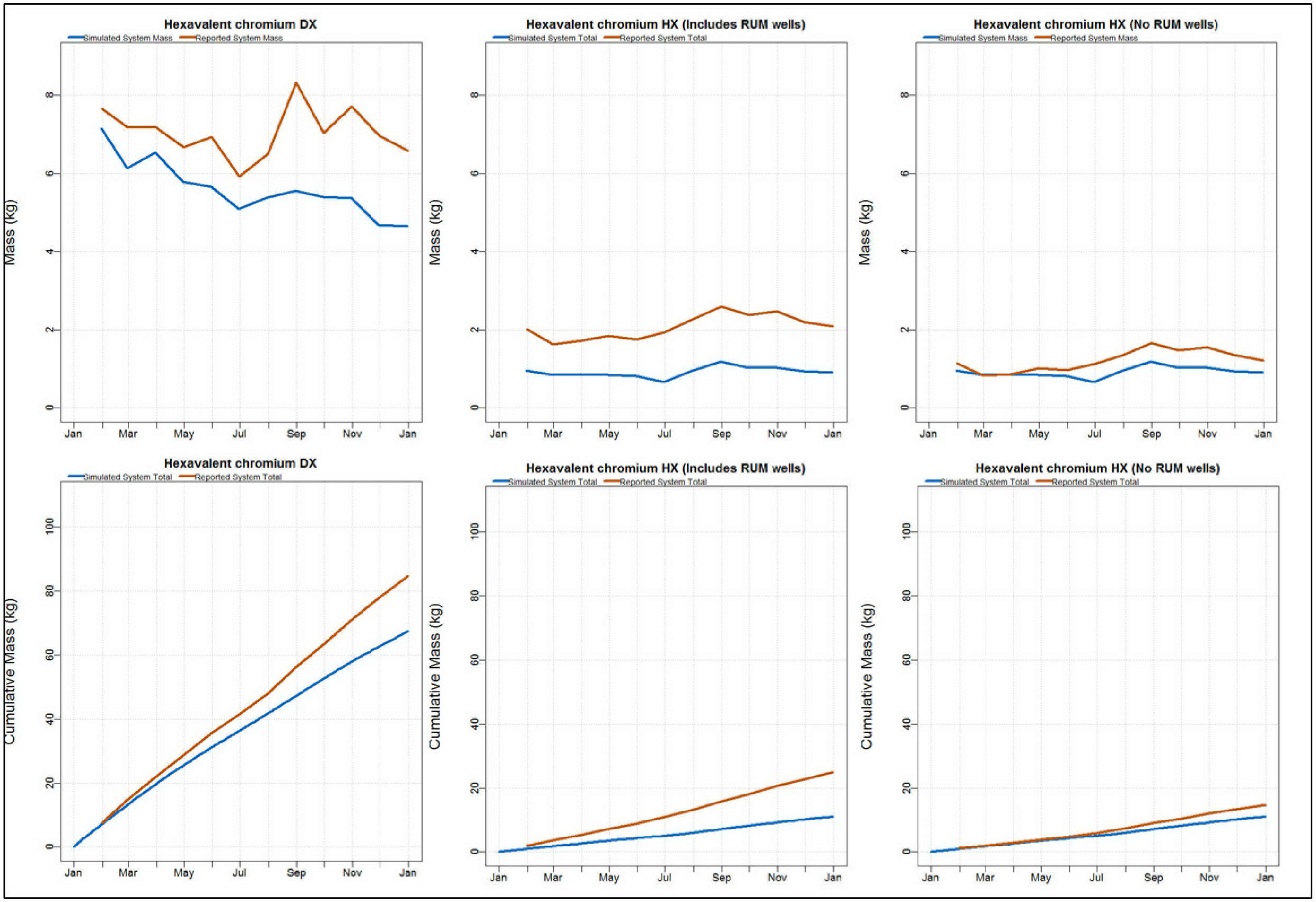


Figure 2-31. Comparison of Observed to Calculated Cr(VI) Mass Removal
(Top Row = Monthly Mass Removal; Bottom Row = Cumulative Mass Removal)

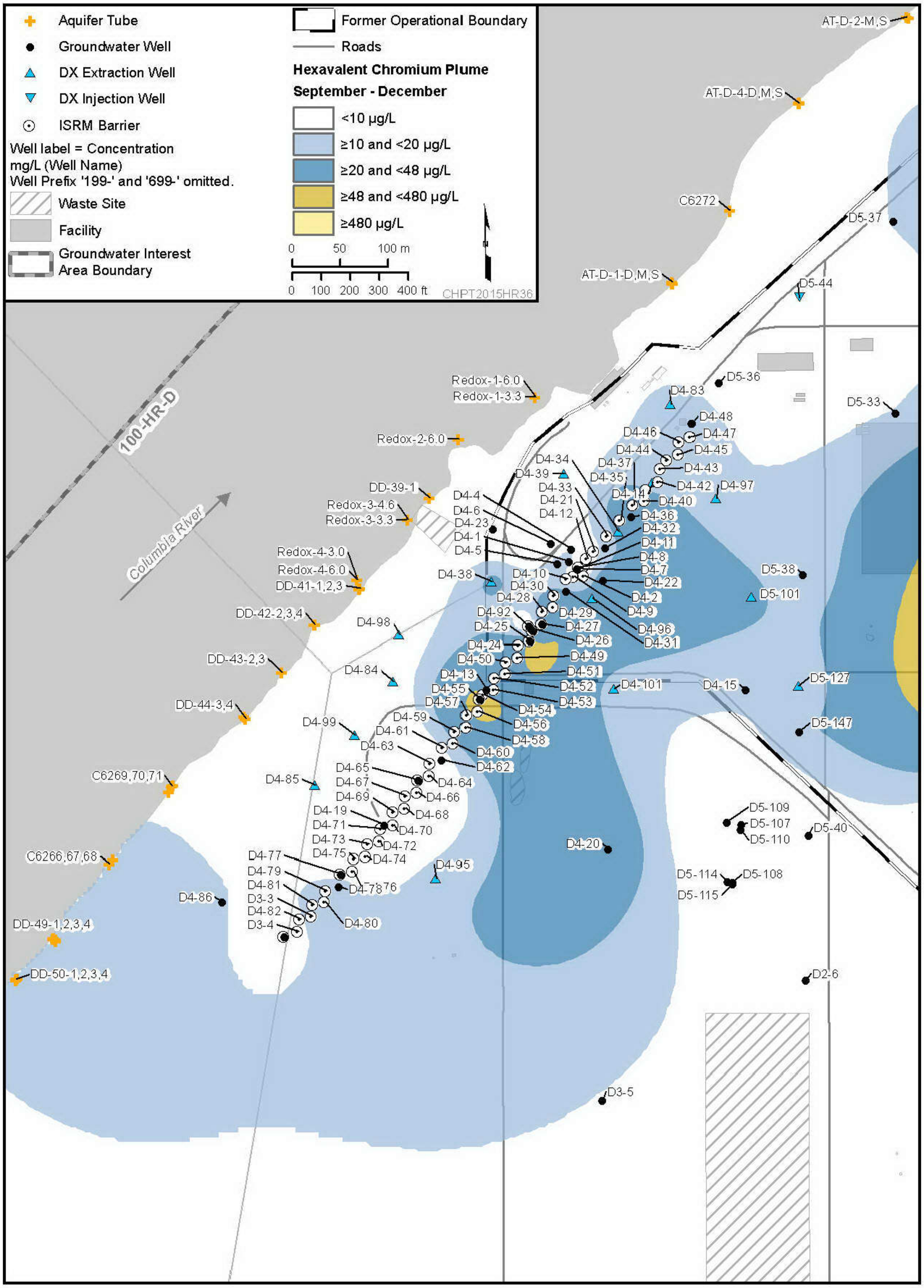
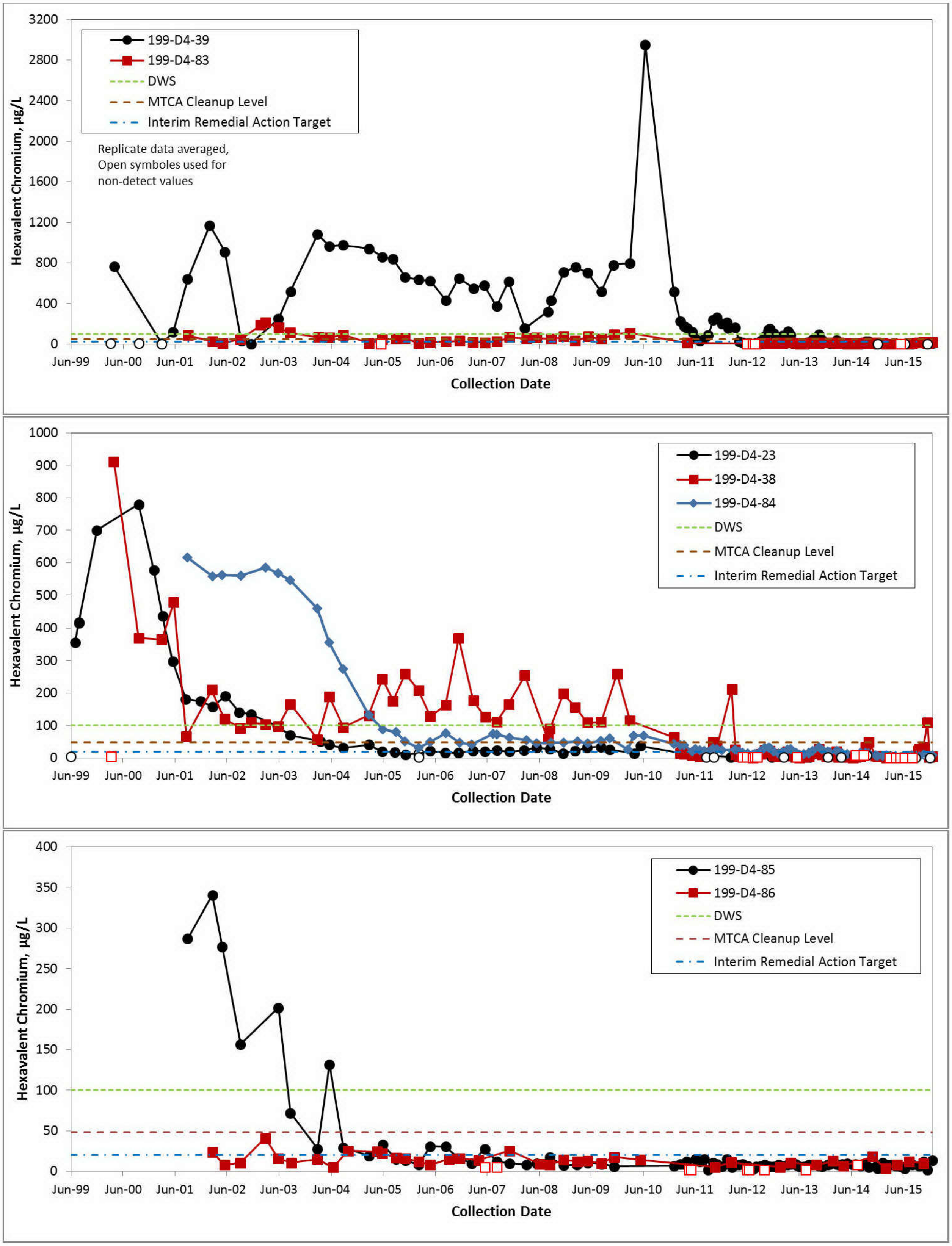
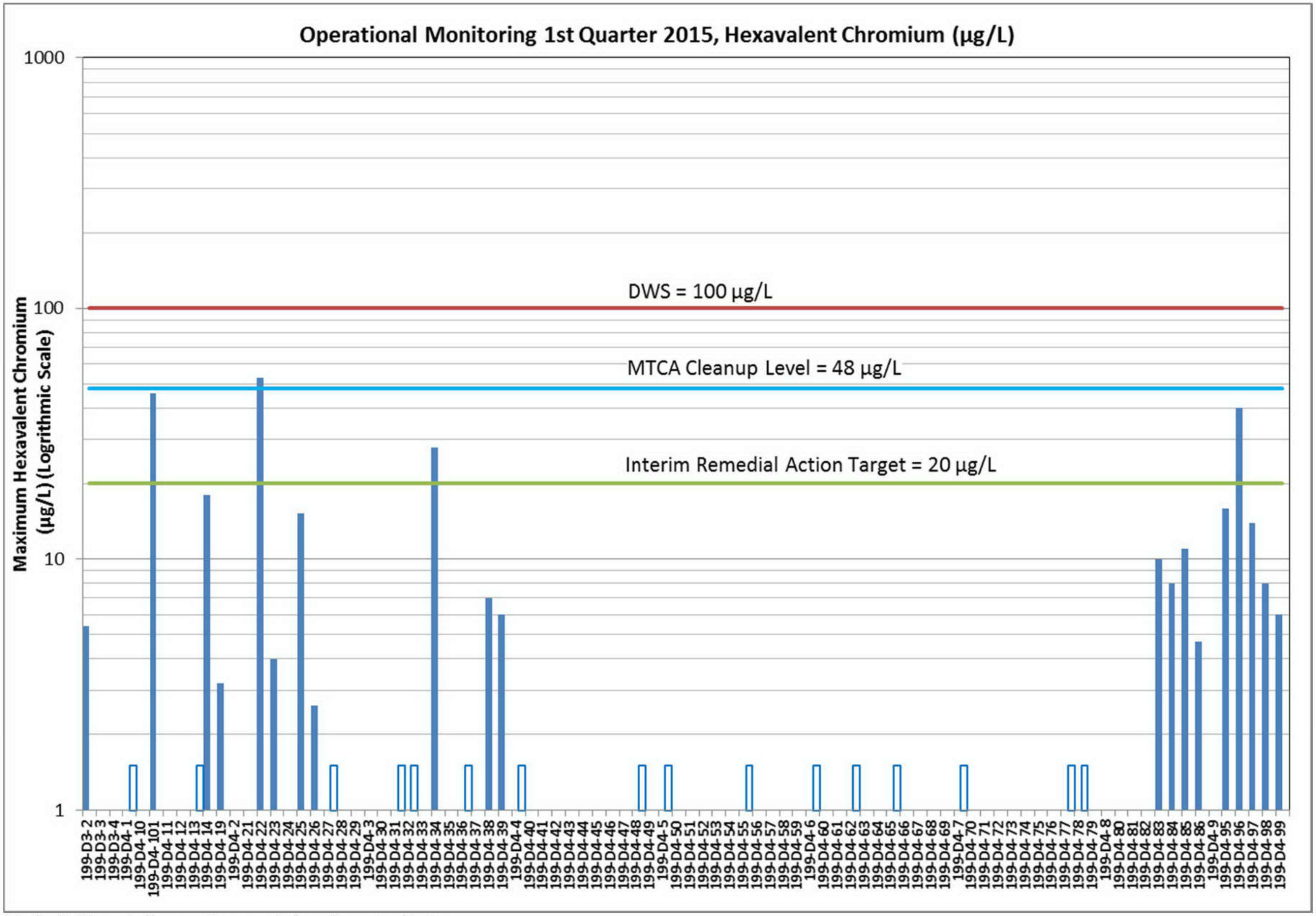


Figure 2-32. ISRM Cr(VI) Map, 2015



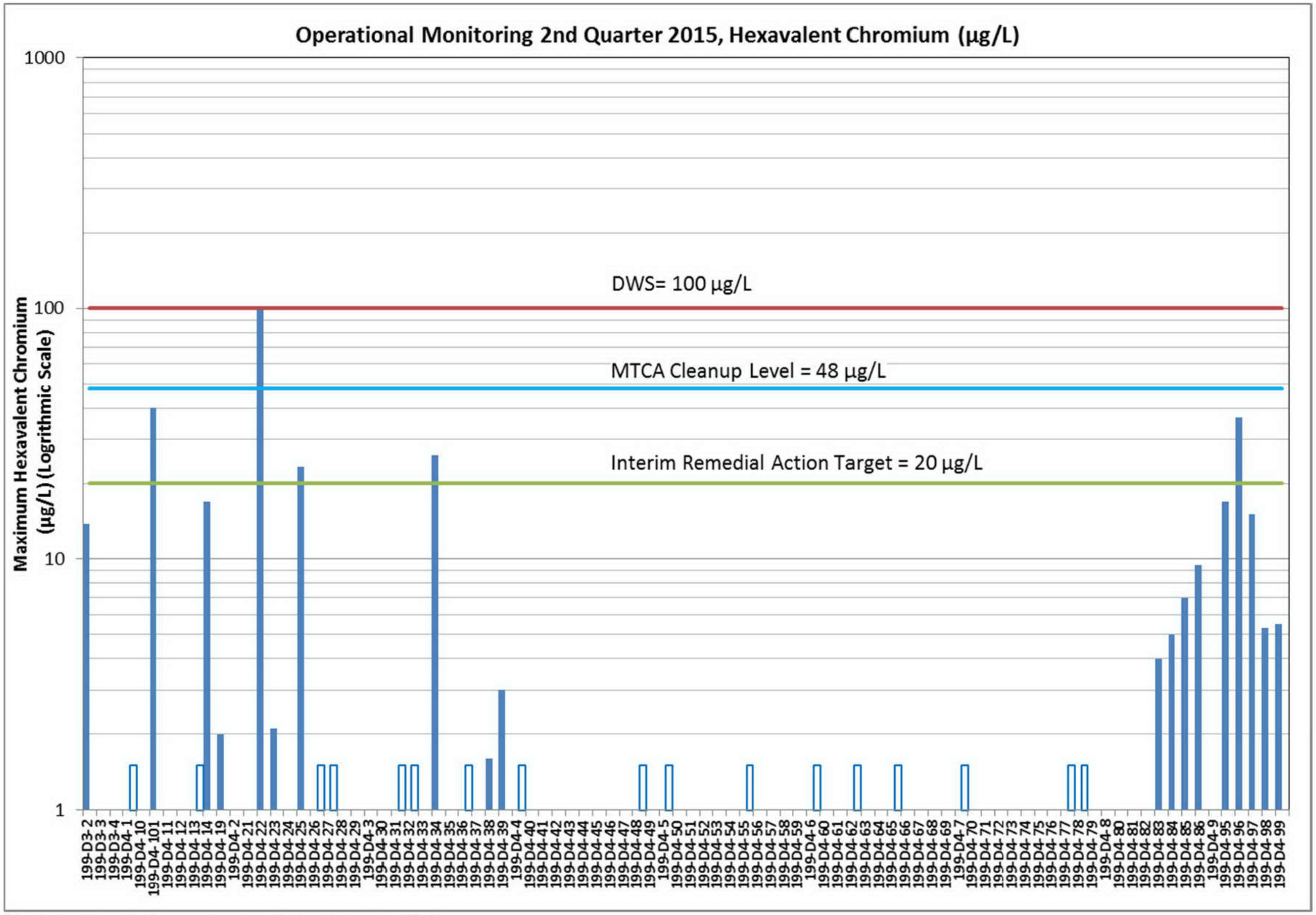
1

2 **Figure 2-33. ISRM Cr(VI) Trend Plots for Compliance Wells**



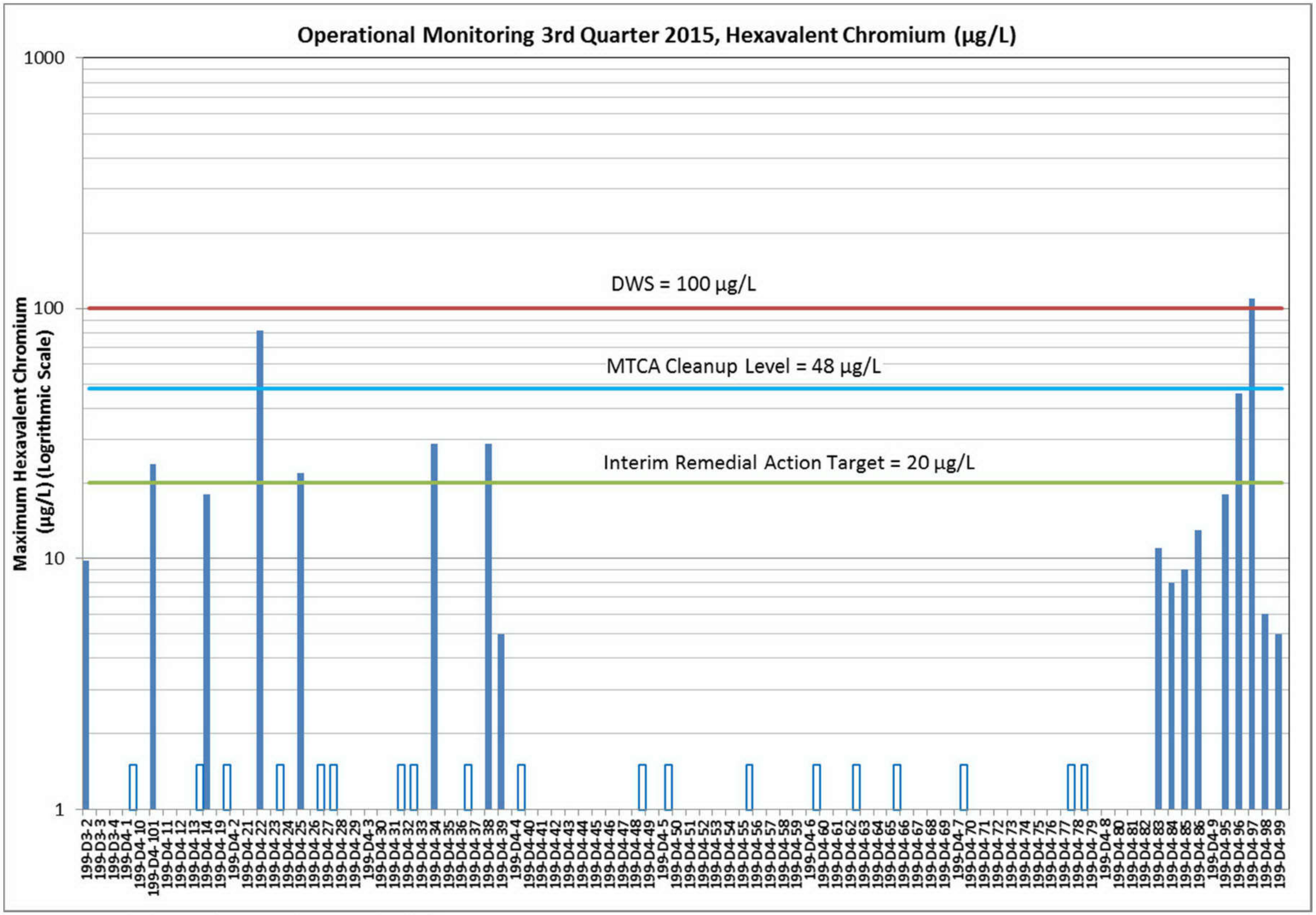
Note: Unshaded bars indicate values are below detection limit.

Figure 2-34. ISRM Operational Monitoring, Cr(VI), First Quarter



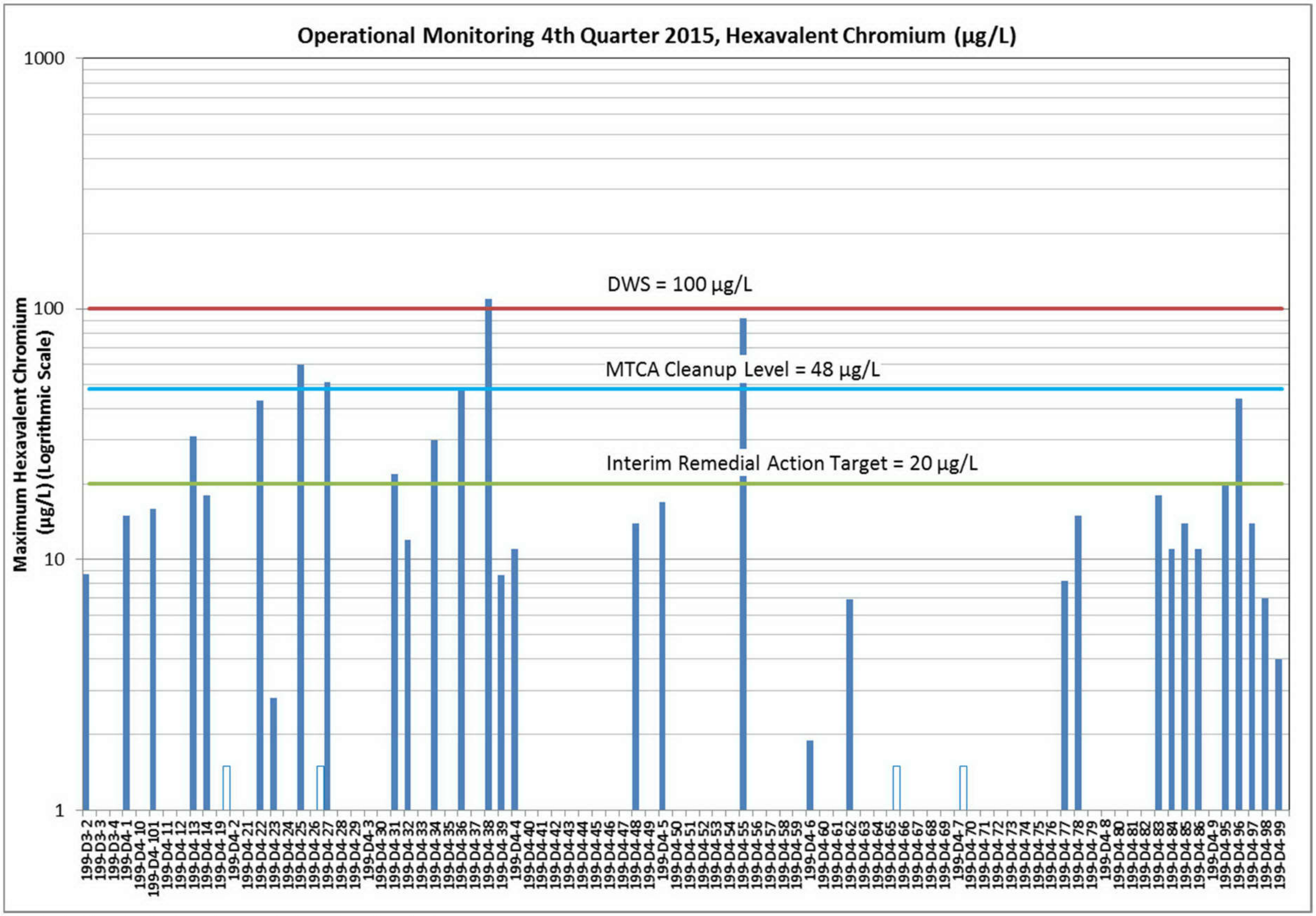
Note: Unshaded bars indicate values are below detection limit.

Figure 2-35. ISRM Operational Monitoring, Cr(VI), Second Quarter



Note: Unshaded bars indicate values are below detection limit.

Figure 2-36. ISRM Operational Monitoring, Cr(VI), Third Quarter



Note: Unshaded bars indicate values are below detection limit.

Figure 2-37. ISRM Operational Monitoring, Cr(VI), Fourth Quarter

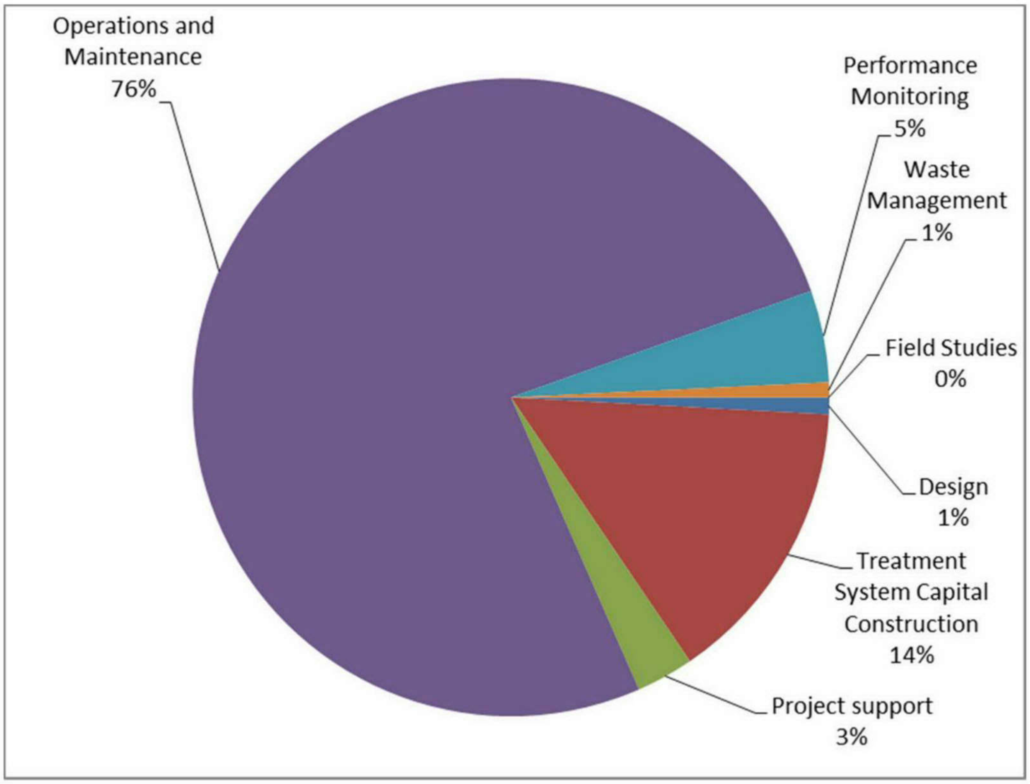


Figure 2-38. DX P&T System, 2015 Cost ($5.68 million) Breakdown (by Percentage)

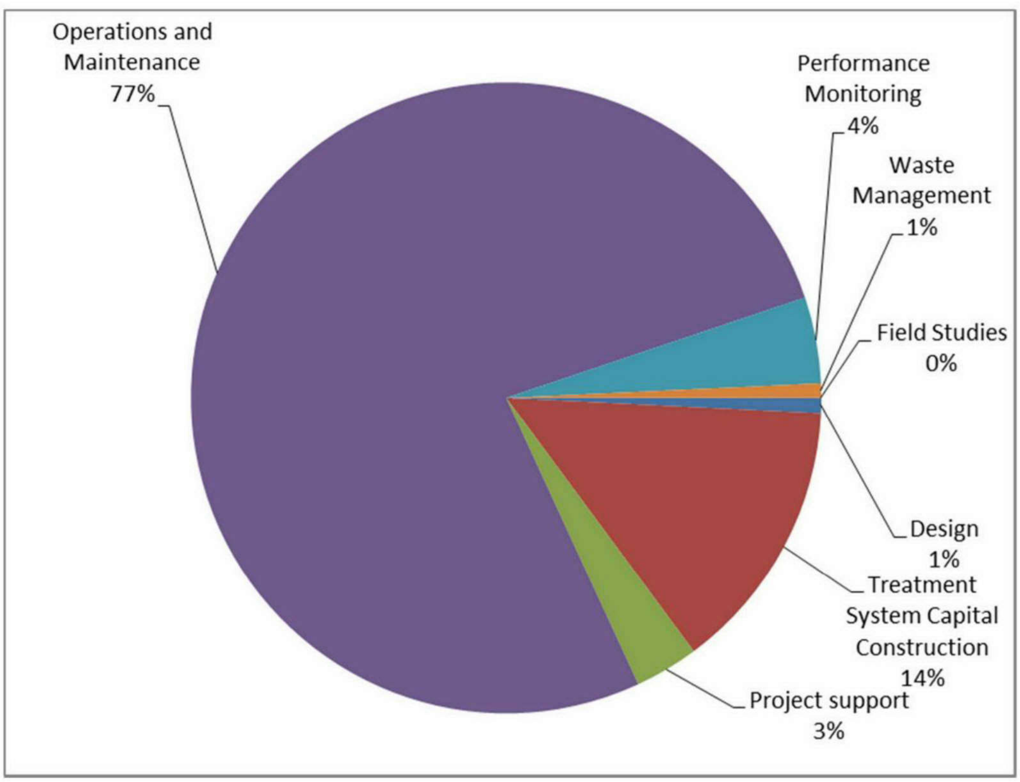


Figure 2-39. HX P&T System, 2015 Cost ($5.03 million) Breakdown (by Percentage)

Table 2-1. 100-HR-3 Groundwater OU Remedial System Well Changes Initiated in 2015

System	Well	Action	Purpose	Status as of December 31, 2015
DX	199-D5-34	Connect as extraction well	River protection/hydraulic control	In service, operating as extraction well
	199-D5-154	Connect as extraction well	River protection/hydraulic control	In service as extraction well
	199-D5-159	Connect as extraction well	River protection/hydraulic control	In service as extraction well
	699-93-48C	Drill and connect as injection well	Operational/plume control	In service as injection well
HX	199-H4-93	Drill and connect as extraction well	Mass removal	In service as extraction well
	199-H4-92	Drill as extraction well; future connection	Mass removal	Drilled
	199-H5-16	Drill as extraction well; future connection	Mass removal	Drilled
	199-H1-46	Drill as extraction well; future connection	River protection/hydraulic control	Drilled
	199-H3-9	Connect as extraction well	Mass removal from RUM	In service as extraction well
	199-H4-86	Connect as extraction well	Mass removal	In service as extraction well
	199-H6-2	Realign from injection to extraction	River protection/hydraulic control	In service as extraction well
	199-H4-74	Realign from injection to extraction	River protection/hydraulic control	In service as extraction well
	199-H3-25	Realign from injection to extraction	Mass removal/plume control	In service as extraction well
	199-H3-26	Realign from injection to extraction	Mass removal/plume control	In service as extraction well
	199-H1-25	Realign from extraction to injection	River protection/hydraulic control	In service as injection well
	199-H1-27	Realign from extraction to injection	River protection/hydraulic control	In service as injection well
	199-H1-6	Realign from extraction to injection	River protection/hydraulic control	In service as injection well
	199-H6-7	Drill and connect as injection well	Operational/plume control	In service as injection well
	199-H6-8	Drill and connect as injection well	Operational/plume control	In service as injection well
	699-95-45B	Drill and connect as injection well	Operational/plume control	In service as injection well
	100-H Area	Reduce injection and extraction flow rates	River protection/plume control	Flows have been adjusted at wells in the H Reactor area

Table 2-2. DX P&T System Operating Parameters and System Performance for 2015

Total DX P&T System Processed Groundwater	2014	2015
Cumulative amount of groundwater treated (since December 2010 startup) (million L)	4,298	5,780
Total amount of groundwater treated during CY (million L)	1,174	1,482
Mass of Hexavalent Chromium Removed	**2014**	**2015**
Cumulative amount of hexavalent chromium removed (since December 2010 startup) (kg)	1,403	1,488
Total amount of hexavalent chromium removed in CY (kg)	179	85
Summary of Operational Parameters	**2014**	**2015**
Average pumping rate (L/min)	2,233	2,818
Average hexavalent chromium influent concentration (µg/L)	145	53.3
Average hexavalent chromium effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	99.1	96.4
Waste generation (m^3)	7.2	3.6
Regenerated resin Spent resin disposed (m^3)	0	21.7[a]
New resin installed (m^3)	4.4[b]	8.8[c]
Number of resin vessel changeouts	1	3
Summary of Other COCs Detected in Effluent		
Average tritium concentration (pCi/L)	2,095	2,193
Average nitrate concentration (µg/L)	25,650	16,841
Average strontium-90 concentration (pCi/L)	0.6	0.8
Average total chromium concentration (µg/L)	27.8	4.0
Summary of Operational and System Availability	**2014**	**2015**
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,699	8,686
Total availability (%)*	99.3%	99.2%

Table 2-2. DX P&T System Operating Parameters and System Performance for 2015

* Total availability [(total time online) ÷ (total possible run-time)].

a. Volume represents the total waste container volumes disposed containing resin. Actual resin volume disposed was 13.2 m^3.

b. The volume reported in DOE/RL-2015-05, *Calendar Year 2014 Annual Summary Report for the 100 HR 3 and 100 KR 4 Pump and Treat Operations, and 100 NR 2 Groundwater Remediation* only included volume for new resin installed in one vessel. The resin in two vessels was replaced in 2014, installing 4.4 m^3 of new resin.

c. New resin was installed in the first vessel of four IX trains, completing the change out started in 2014.

COC = contaminant of concern
CY = calendar year
IX = ion exchange
P&T = pump and treat

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min) Low River Stage Average	Flow Rate L/min (gal/min) High River Stage Average	Total Flow Hours in 2015	Total Run-Time[a] (Percent)	Purpose
B8989	199-D4-38	ME01	29.8 (7.9)	30 (7.9)	8664	98.90%	Extraction
B8990	199-D4-39	ME02	29.4 (7.8)	37.5 (9.9)	7272	83.01%	Extraction
C3315	199-D4-83	ME03	41 (10.8)	51.7 (13.7)	7752	88.49%	Extraction
C3316	199-D4-84	ME04	17.5 (4.6)	19 (5)	8760	100.00%	Extraction
C3317	199-D4-85	ME05	57.1 (15.1)	71.9 (19)	8760	100.00%	Extraction
C7083	199-D4-95	ME06	82.2 (21.7)	85.1 (22.5)	8760	100.00%	Extraction
C7084	199-D4-96	ME07	36.2 (9.6)	44.5 (11.7)	7896	90.14%	Extraction
C7085	199-D4-97	ME08	45.1 (11.9)	45.5 (12)	8760	100.00%	Extraction
C7086	199-D4-98	ME09	42.9 (11.3)	45.3 (12)	8688	99.18%	Extraction
C7087	199-D4-99	ME10	52 (13.7)	71.9 (19)	8760	100.00%	Extraction
C7580	199-D4-101	ME11	41.3 (10.9)	54.6 (14.4)	8760	100.00%	Extraction
C7583	199-D5-101	ME12	90.2 (23.8)	90.9 (24)	8544	97.53%	Extraction
C7591	199-D5-127	ME13	56.4 (14.9)	56.7 (15)	8760	100.00%	Extraction
C5400	199-D5-104	ME14	92.8 (24.5)	91.7 (24.2)	8664	98.90%	Extraction
A4581	199-D8-53	ME21	81.6 (21.5)	82.7 (21.8)	8760	100.00%	Extraction
A4584	199-D8-55	ME22	9.5 (2.5)	15.2 (4)	5928	67.67%	Extraction
B2773	199-D8-69	ME23	73.7 (19.5)	75.1 (19.8)	8712	99.45%	Extraction
B2772	199-D8-68	ME26	187.7 (49.5)	181.5 (47.9)	8760	100.00%	Extraction

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min)		Total Flow Hours in 2015	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7092	199-D8-90	ME27	66 (17.4)	75.5 (19.9)	8760	100.00%	Extraction
C7093	199-D8-91	ME28	73.6 (19.4)	78 (20.6)	8712	99.45%	Extraction
C7582	199-D8-97	ME29	93.9 (24.8)	92.6 (24.5)	8424	96.16%	Extraction
C7589	199-D8-95	ME30	21.5 (5.7)	26.4 (7)	8760	100.00%	Extraction
C7590	199-D5-130	ME31	21.2 (5.6)	31.1 (8.2)	7752	88.49%	Extraction
C7599	199-D7-3	ME32	75.1 (19.8)	75.6 (20)	8760	100.00%	Extraction
C7601	199-D5-131	ME33	71.3 (18.8)	71.4 (18.9)	8760	100.00%	Extraction
C7602	199-D8-98	ME34	71.3 (18.8)	71.4 (18.9)	8760	100.00%	Extraction
C7603	199-D8-96	ME35	78.1 (20.6)	75.5 (19.9)	8760	100.00%	Extraction
C7611	199-D7-6	ME36	67.1 (17.7)	67.7 (17.9)	8760	100.00%	Extraction
C7610	199-H1-5	ME37	75.1 (19.8)	78.1 (20.6)	8712	99.45%	Extraction
C7609	199-H4-82	ME38	85.8 (22.7)	85.6 (22.6)	6576	75.07%	Extraction
C7596	199-H4-81	ME39	55.9 (14.8)	56.7 (15)	8664	98.90%	Extraction
C7595	199-H4-80	ME40	63.5 (16.8)	64.6 (17)	8760	100.00%	Extraction
C9377	199-D5-159[b]	ME41	145.5 (38.4)	107.7 (28.4)	4152	47.40%	Extraction
A4577	199-D5-20	ME42	8 (2.1)	12.3 (3.2)	5760	65.75%	Extraction
C4185	199-D5-32	ME43	67.2 (17.7)	68 (18)	8760	100.00%	Extraction
B8748	199-D5-39	ME44	92.9 (24.5)	89.5 (23.6)	8688	99.18%	Extraction

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min)		Total Flow Hours in 2015	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C4583	199-D5-92	ME45	28 (7.4)	44.6 (11.8)	8568	97.81%	Extraction
C4536	199-D8-88	ME46	11.3 (3)	14.7 (3.9)	8760	100.00%	Extraction
C4474	199-D8-73	ME47	1.2 (0.3)	11.5 (3)	4872	55.62%	Extraction
C7091	199-D8-89	ME48	35.5 (9.4)	57.9 (15.3)	8760	100.00%	Extraction
B8985	199-D4-34	ME49	32.8 (8.7)	37 (9.8)	8760	100.00%	Extraction
B8072	199-D4-14	ME50	41.1 (10.8)	41.6 (11)	8760	100.00%	Extraction
C8726	199-D5-146	ME51	97.5 (25.7)	98.2 (25.9)	8760	100.00%	Extraction
C8789	199-D5-153	ME52	97.5 (25.7)	98.2 (25.9)	8760	100.00%	Extraction
C8790	199-D5-154[b]	ME53	167.9 (44.3)	170 (44.9)	8112	92.60%	Extraction
C4187	199-D5-34[b]	ME54	134.6 (35.5)	63.9 (16.9)	3696	42.19%	Extraction
B8754	199-D5-44	MJ01	66.7 (17.6)	72 (19)	8760	100.00%	Injection
B8752	199-D5-42	MJ02	63.3 (16.7)	72 (19)	8736	99.73%	Injection
C7600	199-D5-129	MJ03	514.4 (135.8)	524 (138.3)	8760	100.00%	Injection
C7612	199-D5-128	MJ04	170.9 (45.1)	180.2 (47.6)	8760	100.00%	Injection
C8728	199-D5-148	MJ05	578.8 (152.8)	594 (156.8)	8760	100.00%	Injection
C8929	699-93-48C[b]	MJ16	277.1 (73.2)	0 (0)	2952	33.70%	Injection
C7090	199-D2-12[c]	MJ17	0 (0)	0 (0)	0	0.00%	Injection

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min)		Total Flow Hours in 2015	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7089	199-D2-10[c]	MJ18	0 (0)	0 (0)	0	0.00%	Injection
C7096	199-D8-94[c]	MJ19	0 (0)	0.2 (0)	264	3.01%	Injection
C7095	199-D8-93[c]	MJ20	0 (0)	0 (0)	0	0.00%	Injection
C7608	199-D7-5	MJ21	524.5 (138.5)	526.8 (139.1)	8760	100.00%	Injection
C7607	199-D6-2	MJ22	72.8 (19.2)	72.7 (19.2)	8760	100.00%	Injection
C7594	199-D7-4	MJ23	561.8 (148.3)	562.3 (148.4)	8760	100.00%	Injection
C7593	199-D8-99	MJ24	0 (0)	143.2 (37.8)	4896	55.89%	Injection
C7592	199-D6-1	MJ25	71.9 (19)	72.6 (19.2)	8616	98.36%	Injection

Note: For purposes of deriving average flow rates for low river and high river stage, flow rates from mid-August through early-December were averaged for low river, and flow rates from mid-April through early-August were averaged for high river.

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. New well connection in 2015

c. High water levels in these injection wells during high river periods limit the amount of water the well can accept. Wells are planned for conversion to monitoring wells and disconnection from the system. As of the end of 2015, the wells are no longer operational.

CY = calendar year

ID = identification

PLC = programmable logic controller

Table 2-4. HX P&T System Operating Parameters and System Performance for 2015

Total HX P&T System Processed Groundwater	2014	2015
Cumulative amount of groundwater treated (since September 2011 startup) (million L)	4,081	5,204
Total amount of groundwater treated in CY (million L)	1,178	1,123
Mass of Hexavalent Chromium Removed	**2014**	**2015**
Cumulative amount of hexavalent chromium removed (since September 2011 startup) (kg)	93.1	118.0
Total amount of hexavalent chromium removed in CY (kg)	22.8	24.9
Summary of Operational Parameters	**2014**	**2015**
Average pumping rate (L/min)	2,240	2,138
Average hexavalent chromium influent concentration (µg/L)	20	23.3
Average hexavalent chromium effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	95.9	95.0
Waste generation (m^3)	3.6	3.6
Spent resin disposed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of Other COCs Detected in Effluent		
Average tritium concentration (pCi/L)	464	1,050
Average nitrate concentration (µg/L)	6,438	14,400
Average strontium-90 concentration (pCi/L)	0.7	1.0
Average total chromium concentration (µg/L)	1.0	1.6
Summary of Operational and System Availability	**2014**	**2015**
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,698	8,633
Total availability (%)*	99.3%	98.6%

* Total availability [(total time online) ÷ (total possible run-time)].

COC = contaminant of concern

CY = calendar year

P&T = pump and treat

1

Table 2-5. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells for 2015

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours 2015	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7477	199-H1-45	HE01	102.1 (27)	102.1 (27)	8688	99.18%	Extraction
A4621	199-H4-15A	HE02	77.9 (20.6)	117.3 (31)	8688	99.18%	Extraction
C7485	199-H4-69	HE03	44.5 (11.7)	87.1 (23)	8688	99.18%	Extraction
C7483	199-H4-70	HE04	20.8 (5.5)	87 (23)	7872	89.86%	Extraction
C7597	199-H4-75	HE05	41.4 (10.9)	75.3 (19.9)	8208	93.70%	Extraction
A4630	199-H4-4	HE06	12.3 (3.3)	41.3 (10.9)	5832	66.58%	Extraction
B2776	199-H4-63	HE07	102.6 (27.1)	103.1 (27.2)	8640	98.63%	Extraction
B2777	199-H4-64	HE08	25.8 (6.8)	75.3 (19.9)	8664	98.90%	Extraction
A4613	199-H3-2C	HE09	93.1 (24.6)	96.3 (25.4)	8688	99.18%	Extraction
A4618	199-H4-12C	HE10	110.6 (29.2)	112.2 (29.6)	8688	99.18%	Extraction
C7489	199-H6-2[b, c]	HE11	12.5 (3.3)	0 (0)	672	7.67%	Extraction
C7639	199-H3-9[d]	HE13	69.3 (18.3)	0 (0)	744	8.49%	Extraction
C7108	199-H1-34	HE21	28.8 (7.6)	78.9 (20.8)	8736	99.73%	Extraction
C7106	199-H1-35	HE22	58.1 (15.3)	105.9 (28)	8736	99.73%	Extraction
C7102	199-H1-36	HE23	12.8 (3.4)	33.1 (8.7)	8736	99.73%	Extraction
C7099	199-H1-37	HE24	35.7 (9.4)	102.7 (27.1)	6000	68.49%	Extraction
C7098	199-H1-38	HE26	9.3 (2.4)	39.7 (10.5)	5160	58.90%	Extraction
C7109	199-H1-39	HE27	0 (0)	90.4 (23.9)	4704	53.70%	Extraction

Table 2-5. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells for 2015

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours 2015	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7104	199-H1-40	HE28	0 (0)	32.4 (8.6)	4752	54.25%	Extraction
C7107	199-H1-42	HE29	20.4 (5.4)	67.3 (17.8)	7224	82.47%	Extraction
C7492	199-H1-43	HE30	113.5 (30)	113.5 (30)	8736	99.73%	Extraction
C7581	199-H1-3[c]	HE31	0 (0)	0 (0)	0	0.00%	Extraction
C7584	199-H1-2	HE32	8.4 (2.2)	11.3 (3)	8160	93.15%	Extraction
C7585	199-H1-1	HE33	106.7 (28.2)	108.9 (28.8)	8736	99.73%	Extraction
C7587	199-H4-76	HE34	6.2 (1.6)	14.2 (3.8)	2928	33.42%	Extraction
C7604	199-H1-4	HE35	6.9 (1.8)	4.5 (1.2)	3912	44.66%	Extraction
C7605	199-H4-77	HE36	30.3 (8)	30.5 (8)	8736	99.73%	Extraction
C7115	199-H3-26[b]	HE37	118.2 (31.2)	18.6 (4.9)	3720	42.47%	Extraction
C7110	199-H3-25[b]	HE38	295.2 (77.9)	100.9 (26.6)	7344	83.84%	Extraction
C7598	199-H4-74[b]	HE39	14.6 (3.9)	102.1 (27)	5928	67.67%	Extraction
C7100	199-H1-32	HE40	9.6 (2.5)	19.2 (5.1)	5472	62.47%	Extraction
C7105	199-H1-33	HE41	35.7 (9.4)	92.3 (24.4)	6024	68.77%	Extraction
B2779	199-H3-4	HE42	283.4 (74.8)	491.2 (129.7)	8688	99.18%	Extraction
C8724	199-H4-86[d]	HE44	127.5 (33.7)	0 (0)	3816	43.56%	Extraction
C8949	199-H4-93[d]	HE46	24.7 (6.5)	0 (0)	2208	25.21%	Extraction
C7489	199-H6-2[b, c]	HJ01	0 (0)	102.2 (27)	3816	43.56%	Injection

Table 2-5. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells for 2015

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours 2015	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7484	199-H4-73	HJ02	53.9 (14.2)	119.2 (31.5)	7728	88.22%	Injection
C7488	199-H4-72	HJ03	80.7 (21.3)	165.3 (43.6)	8736	99.73%	Injection
C7483	199-H4-71	HJ04	69.4 (18.3)	160.3 (42.3)	6552	74.79%	Injection
A4628	199-H4-18	HJ05	33.2 (8.8)	47.6 (12.6)	7728	88.22%	Injection
C7114	199-H3-27	HJ06	84.8 (22.4)	192 (50.7)	8592	98.08%	Injection
C7606	199-H1-6[e]	HJ07	120 (31.7)	226.7 (59.8)	7896	90.14%	Injection
C7478	199-H1-25[e]	HJ08	105.4 (27.8)	226.9 (59.9)	8112	92.60%	Injection
C7480	199-H1-27[e]	HJ09	111.2 (29.3)	191.5 (50.6)	7728	88.22%	Injection
C7588	199-H4-78	HJ10	153.2 (40.4)	321.9 (85)	8736	99.73%	Injection
C7586	199-H4-79	HJ11	152.3 (40.2)	292.5 (77.2)	8640	98.63%	Injection
C7111	199-H1-21	HJ12	103.5 (27.3)	271.4 (71.7)	8736	99.73%	Injection
C7113	199-H1-20	HJ13	106.3 (28.1)	179.6 (47.4)	8736	99.73%	Injection
A4627	199-H4-17	HJ14	22.5 (5.9)	38.4 (10.1)	7608	86.85%	Injection
C8947	199-H6-7[d]	HJ22	240.7 (63.6)	0 (0)	3432	39.18%	Injection
C8951	199-H6-8[d]	HJ23	246.7 (65.1)	0 (0)	3336	38.08%	Injection
C8950	699-95-45B[d]	HJ24	199.3 (52.6)	0 (0)	3432	39.18%	Injection

Note: For purposes of deriving average flow rates for low river and high river stage, flow rates from mid-August through early-December were averaged for low river, and flow rates from mid-April through early-August were averaged for high river.

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. Well realigned from injection to extraction

Table 2-5. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells for 2015

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours 2015	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			

c. Flows at the well are minimal. Well is being reevaluated for removal from the system. Well 199-H1-3 is not operating.

d. New well connection in 2015

e. Well realigned from extraction to injection

CY = calendar year

ID = identification

PLC = programmable logic controller

Table 2-6. 2015 Maximum Contaminant and Co-Contaminant Concentrations for 100-D Area

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
Hexavalent chromium	611	F	5/13/2015	199-D5-34
Hexavalent chromium	614	UF	5/13/2015	199-D5-34
Total chromium	587	F	5/13/2015	199-D5-34
Total chromium	613	UF	5/13/2015	199-D5-34
Nitrate	45,200	UF	5/14/2015	199-D2-6
Strontium-90	32.7	UF	8/24/2015	199-D5-132
Tritium	14,400	UF	10/9/2015	199-D4-20
Technetium-99	Not detected	—	—	—
Sulfate	222,000	UF	4/10/2015	199-D8-101
Uranium	25.7	F	7/6/2015	699-93-48C

Table 2-6. 2015 Maximum Contaminant and Co-Contaminant Concentrations for 100-D Area

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
Uranium	12.2	UF	7/6/2015	699-93-48C
Gross beta	70.5	UF	11/13/2015	199-D5-132
Gross alpha	5.19	UF	8/13/2015	199-D5-145

Note: This table considers those wells included in the 100-D groundwater area of interest, with the exception of those wells screened in the Ringold Formation upper mud unit (199-D5-134, 199-D5-141, 199-D8-54B, and 699-97-48C).

Table 2-7. 2015 Maximum Contaminant and Co-Contaminant Concentrations for 100-H and Horn Area

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
Hexavalent chromium	96	F	12/1/2015	199-H1-7
Hexavalent chromium	100	UF	9/14/2015	199-H4-93
Total chromium	116	F	12/1/2015	199-H1-7
Total chromium	135	UF	12/1/2015	199-H1-7
Nitrate	33,900	UF	5/7/2015	199-H6-3
Strontium-90	28	UF	5/13/2015	199-H4-83
Tritium	3,260	UF	10/29/2015	699-96-43
Technetium-99	25.8	UF	6/26/2015	199-H4-84
Sulfate	130,000	UF	11/4/2015	699-94-43
Uranium	51.7	F	6/15/2015	699-97-47B
Uranium	39.1	UF	5/7/2015	199-H4-93

Table 2-7. 2015 Maximum Contaminant and Co-Contaminant Concentrations for 100-H and Horn Area

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
Gross beta	57.8	UF	12/3/2015	199-H4-83
Gross alpha	21	UF	2/26/2015	199-H4-85

Note: This table considers wells included in the 100-H groundwater area of interest, with the exception of those wells screened in the Ringold Formation upper mud unit (199-H2-1, 199-H3-2C, 199-H3-9, 199-H3-10, 199-H4-12C, 199-H4-15CS, 699-97-43C, and 699-97-45B) or other deeper aquifer wells (199-H4-15CQ and 199-H4-15CR).

Table 2-8. 2015 Maximum Contaminant and Co-Contaminant Concentrations for 100-H Area and 100-D Area RUM Wells

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
Hexavalent chromium	130	F	8/12/2015	199-H4-12C
Hexavalent chromium	137	UF	10/5/2015	199-H4-12C
Total chromium	144	F	10/29/2015	699-97-48C
Total chromium	158	UF	10/29/2015	699-97-48C
Nitrate	17,700	UF	11/11/2015	199-H4-12C
Strontium-90	6.05	UF	11/11/2015	199-H4-12C[a]
Tritium	1,580	UF	10/28/2015	199-D5-134
Technetium-99	12	UF	11/11/2015	199-H3-9
Sulfate	95,000	UF	11/11/2014	199-H4-12C
Uranium	3.55	F	12/7/2015	199-D8-54B
Uranium	3.51	UF	12/7/2015	199-D8-54B
Gross beta	14.4	UF	11/11/2015	199-H4-12C

Table 2-8. 2015 Maximum Contaminant and Co-Contaminant Concentrations for 100-H Area and 100-D Area RUM Wells

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
Gross alpha	2.2	UF	11/13/2015	199-H2-1

Note: This table considers wells included in the 100-D and 100-H groundwater areas of interest that are screened in the Ringold Formation upper mud unit (100-D: 199-D5-134, 199-D5-141, 199-D8-54B, 699-97-61, and 699-97-48C; and 100-H: 199-H2-1, 199-H3-2C, 199-H3-9, 199-H3-10, 199-H4-12C, 199-H4-15CS, 699-97-60, 699-97-43C, and 699-97-45B).

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-D2-11	M	5/18/2015	1.6	11/11/2015	1.5 (U)	2/5/2015	2
ISRM	199-D2-6	M	5/14/2015	10.9	10/30/2015	3.5	5/14/2015	10.9
ISRM	199-D3-2	M	5/29/2015	13.3	12/16/2015	7.3	5/29/2015	13.3
	199-D3-5	M	5/14/2015	6.6	10/30/2015	2.7	8/13/2015	9.4
ISRM	199-D4-1	M	—	—	12/16/2015	15	12/16/2015	15
DX	199-D4-101	E	5/13/2015	26	9/21/2015	18	3/10/2015	46
ISRM	199-D4-13	M	—	—	10/22/2015	31	10/22/2015	31
DX	199-D4-14	E	5/6/2015	17	12/7/2015	18	12/7/2015	18
ISRM	199-D4-15	M	—	—	10/9/2015	7.1	10/9/2015	7.1
ISRM	199-D4-19	M	4/17/2015	2	10/22/2015	1.5 (U)	1/16/2015	2.4
ISRM	199-D4-20	M	—	—	10/9/2015	33	10/9/2015	33

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
ISRM	199-D4-22	M	6/18/2015	79.5	8/28/2015	75	6/18/2015	79.5
ISRM	199-D4-23	C	5/29/2015	1.8	12/7/2015	2.8	2/27/2015	4
	199-D4-25	M	6/14/2015	22.9	12/7/2015	60	12/7/2015	60
	199-D4-26	M	7/17/2015	1.5 (U)	10/19/2015	1.5 (U)	1/16/2015	2.6
	199-D4-27	M	—	—	12/7/2015	51	12/7/2015	51
ISRM	199-D4-31	T	—	—	12/14/2015	22	12/14/2015	22
ISRM	199-D4-32	T	—	—	12/16/2015	11	12/16/2015	11
DX	199-D4-34	E	5/6/2015	26	12/7/2015	30	12/7/2015	30
ISRM	199-D4-36	T	—	—	12/14/2015	46	12/14/2015	46
DX	199-D4-38	E	7/28/2015	3	11/18/2015	110	11/18/2015	110
DX	199-D4-39	E	7/28/2015	5	11/11/2015	8.5	11/11/2015	8.5
ISRM	199-D4-4	M	—	—	12/18/2015	8.5	12/18/2015	8.5
ISRM	199-D4-48	T	—	—	12/16/2015	13	12/16/2015	13
ISRM	199-D4-5	M	—	—	10/26/2015	16	10/26/2015	16
	199-D4-55	M	—	—	11/13/2015	91	11/13/2015	91
ISRM	199-D4-6	M	—	—	10/9/2015	1.5 (U)	10/9/2015	1.5 (U)
ISRM	199-D4-62	T	6/14/2015	1.5 (U)	12/18/2015	6.7	12/18/2015	6.7
	199-D4-65	M	—	—	11/13/2015	1.5 (U)	11/13/2015	1.5 (U)

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
ISRM	199-D4-7	T	—	—	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	199-D4-77	M	—	—	11/13/2015	7.4	11/13/2015	7.4
ISRM	199-D4-78	T	—	—	10/23/2015	14	10/23/2015	14
DX	199-D4-83	E	7/28/2015	7	11/11/2015	18	11/11/2015	18
DX	199-D4-84	E	7/28/2015	8	10/20/2015	11	10/20/2015	11
DX	199-D4-85	E	7/28/2015	9	12/21/2015	14	12/21/2015	14
ISRM	199-D4-86	C	7/10/2015	11.9	10/23/2015	9.1	7/10/2015	11.9
	199-D4-92	M	7/17/2015	1.5 (U)	10/19/2015	1.5 (U)	10/19/2015	1.5 (U)
	199-D4-93	M	7/17/2015	1.5 (U)	10/23/2015	1.5 (U)	10/23/2015	1.5 (U)
DX	199-D4-95	E	7/27/2015	17.7	12/21/2015	20	12/21/2015	20
DX	199-D4-96	E	7/27/2015	46	12/21/2015	44	7/27/2015	46
DX	199-D4-97	E	7/28/2015	110	12/21/2015	14	7/28/2015	110
DX	199-D4-98	E	7/27/2015	5.6	10/20/2015	7	1/8/2015	8
DX	199-D4-99	E	7/27/2015	4	9/21/2015	5	1/8/2015	6
DX	199-D5-101	E	7/28/2015	24	12/21/2015	34	12/21/2015	34
	199-D5-103	M	4/16/2015	169	9/11/2015	78	1/16/2015	246
DX	199-D5-104	E	4/23/2015	315	9/1/2015	253	1/8/2015	440
	199-D5-106	M	5/18/2015	15.3	11/13/2015	6.7	5/18/2015	15.3

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-D5-107	M	—	—	10/28/2015	1.5 (U)	1/6/2015	11.1
	199-D5-108	M	—	—	10/23/2015	7.6	10/23/2015	7.6
	199-D5-109	M	—	—	10/27/2015	1.5 (U)	10/27/2015	1.5 (U)
	199-D5-110	M	—	—	10/23/2015	1.5 (U)	10/23/2015	1.5 (U)
	199-D5-114	M	—	—	10/23/2015	5.8	10/23/2015	5.8
	199-D5-115	M	—	—	10/23/2015	4.1	10/23/2015	4.1
	199-D5-123	M	5/29/2015	28.4	12/18/2015	17	2/27/2015	29.2
	199-D5-125	M	6/7/2015	49.1	9/18/2015	42	3/13/2015	51.4
	199-D5-126	M	6/7/2015	38.2	9/28/2015	23	3/13/2015	61.8
DX	199-D5-127	E	7/27/2015	15.3	10/19/2015	14	1/8/2015	27
	199-D5-13	M	6/26/2015	142	10/9/2015	120	1/27/2015	185
DX	199-D5-130	E	4/15/2015	31	9/21/2015	29	2/3/2015	33
DX	199-D5-131	E	4/15/2015	123	10/19/2015	75	1/8/2015	139
	199-D5-132	M	—	—	11/13/2015	15	2/5/2015	29
	199-D5-133	M	5/18/2015	3.3	11/8/2015	3.5	8/13/2015	4
	199-D5-14	M	5/28/2015	25.9	10/23/2015	16	1/27/2015	42.3
	199-D5-142	M	5/29/2015	8.8	9/10/2015	5.9	2/27/2015	8.9
	199-D5-143	M	5/20/2015	50.5	11/30/2015	49	2/27/2015	68.2

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-D5-145	M	7/22/2015	192	9/11/2015	140	7/22/2015	192
DX	199-D5-146	E	4/23/2015	50	11/11/2015	18	1/8/2015	64
	199-D5-147	M	5/28/2015	7.2	11/16/2015	1.5 (U)	8/25/2015	25
	199-D5-15	M	5/29/2015	10.2	12/14/2015	5.9	2/27/2015	13.1
DX	199-D5-153	E	4/23/2015	74	9/23/2015	49	1/8/2015	96
DX	199-D5-154	E	5/6/2015	67	9/23/2015	51	2/10/2015	123
DX	199-D5-159	E	7/28/2015	69	9/23/2015	79	3/23/2015	96.4
	199-D5-16	M	5/29/2015	60.5	12/16/2015	27	5/29/2015	60.5
	199-D5-17	M	6/26/2015	11.9	10/23/2015	8.7	1/27/2015	18.2
	199-D5-18	M	5/13/2015	9.3	10/29/2015	7.6	5/13/2015	9.3
	199-D5-19	M	—	—	10/23/2015	23	10/23/2015	23
DX	199-D5-20	E	5/6/2015	17	—	—	1/8/2015	22
DX	199-D5-32	E	5/6/2015	56	9/23/2015	38	1/15/2015	73.5
	199-D5-33	M	6/26/2015	46.8	10/16/2015	10	6/26/2015	46.8
DX	199-D5-34	E	5/13/2015	614	9/1/2015	396	5/13/2015	614
	199-D5-36	M	6/26/2015	10.5	10/26/2015	7.3	1/30/2015	13.5
	199-D5-37	M	6/26/2015	8.6	10/26/2015	9.6	10/26/2015	9.6
ISRM	199-D5-38	M	5/29/2015	12.7	11/16/2015	13	11/16/2015	13

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
DX	199-D5-39	E	4/23/2015	113	12/28/2015	110	4/23/2015	113
	199-D5-40	M	7/16/2015	5.5	10/29/2015	5	2/5/2015	13.8
	199-D5-41	M	5/18/2015	1.5 (U)	11/13/2015	1.5 (U)	11/13/2015	1.5 (U)
ISRM	199-D5-43	M	5/29/2015	8.7	12/18/2015	3.7	5/29/2015	8.7
DX	199-D5-92	E	5/6/2015	14	11/11/2015	25	11/11/2015	25
	199-D5-97	M	5/14/2015	8.4	11/11/2015	4	2/19/2015	17.7
	199-D6-3	M	5/28/2015	3.7	11/8/2015	4.4	2/5/2015	7.7
DX	199-D7-3	E	4/15/2015	12	12/21/2015	10	1/8/2015	19
DX	199-D7-6	E	4/15/2015	8	12/21/2015	6	3/11/2015	14
	199-D8-101	M	7/21/2015	13.9	10/28/2015	13	7/21/2015	13.9
	199-D8-4	M	7/10/2015	156	10/26/2015	140	4/10/2015	270
	199-D8-5	M	5/29/2015	4.4	12/7/2015	4.1	5/29/2015	4.4
DX	199-D8-53	E	6/11/2015	7.6	12/21/2015	10	12/21/2015	10
DX	199-D8-54A	M	7/31/2015	13.3	12/28/2015	14	12/28/2015	14
DX	199-D8-55	E	7/28/2015	16	—	—	7/28/2015	16
DX	199-D8-68	E	4/15/2015	21	12/21/2015	30	12/21/2015	30
DX	199-D8-69	E	6/11/2015	13.9	12/21/2015	11	3/11/2015	14
	199-D8-70	C	5/29/2015	12.2	8/28/2015	8.1	3/13/2015	13.7

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-D8-71	C	5/20/2015	19.4	11/6/2015	16	2/26/2015	20.5
DX	199-D8-72	M	5/29/2015	7.1	8/28/2015	4.2	1/16/2015	77.6
DX	199-D8-73	E	5/6/2015	65	—	—	1/15/2015	85.2
DX	199-D8-88	E	5/6/2015	12	9/23/2015	10	1/8/2015	37
DX	199-D8-89	E	5/6/2015	60	9/23/2015	74	9/23/2015	74
DX	199-D8-90	E	7/28/2015	11	10/19/2015	7.1	2/3/2015	16
DX	199-D8-91	E	7/28/2015	16	9/21/2015	19	9/21/2015	19
DX	199-D8-95	E	5/20/2015	372	10/19/2015	370	5/20/2015	372
DX	199-D8-96	E	7/27/2015	170	10/19/2015	180	1/8/2015	202
DX	199-D8-97	E	4/15/2015	95	10/19/2015	79	1/8/2015	121
DX	199-D8-98	E	7/27/2015	25.6	11/18/2015	22	4/14/2015	26.1
DX	199-H1-5	E	6/11/2015	20	12/21/2015	21	12/21/2015	21
DX	199-H4-80	E	6/11/2015	22.3	10/20/2015	23	10/20/2015	23
DX	199-H4-81	E	6/11/2015	27.3	12/21/2015	27	6/11/2015	27.3
DX	199-H4-82	E	4/15/2015	17	10/1/2015	19	2/3/2015	21
	699-93-48A	M	5/28/2015	8.7	11/4/2015	8.3	2/11/2015	10
	699-93-48C	I/M	7/6/2015	11.2	—	—	7/6/2015	11.2
	699-95-48	M	5/29/2015	19.8	11/5/2015	17	5/29/2015	19.8

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	699-95-51	M	5/29/2015	14.1	11/5/2015	5.8	2/26/2015	14.5
	699-96-52B	M	5/29/2015	3.2	11/30/2015	9.3	2/23/2015	16.2
	699-97-48B	M	—	—	10/29/2015	23	10/29/2015	23
	699-97-51A	M	5/19/2015	12.9	11/4/2015	9.3	2/11/2015	13.8
	699-97-61	M	—	—	10/29/2015	120	10/29/2015	120
	699-98-49A	M	5/19/2015	1.5 (U)	11/4/2015	1.5 (U)	11/4/2015	1.5 (U)
	699-98-51	M	5/28/2015	8.5	11/1/2015	11	8/26/2015	12
Aquifer Sampling Tubes								
	36-M	AT	—	—	—	—	1/12/2015	8
	36-S	AT	—	—	12/8/2015	1.8	12/8/2015	1.8
	38-M	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	AT-D-1-D	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	AT-D-1-M	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	AT-D-1-S	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	AT-D-2-M	AT	—	—	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	AT-D-2-S	AT	7/27/2015	1.5 (U)	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	AT-D-3-D	AT	—	—	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	AT-D-3-M	AT	—	—	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	AT-D-3-S	AT	—	—	12/8/2015	3.2	12/8/2015	3.2
	AT-D-4-D	AT	—	—	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	AT-D-5-D	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	AT-D-5-M	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	C6266	AT	5/11/2015	9.5	12/7/2015	2.9	5/11/2015	9.5
	C6267	AT	5/11/2015	6.5	12/7/2015	23	12/7/2015	23
	C6268	AT	5/11/2015	7.6	12/7/2015	9.5	12/7/2015	9.5
	C6269	AT	5/11/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	C6270	AT	5/11/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	C6271	AT	5/12/2015	3.6	12/7/2015	8.7	12/7/2015	8.7
	C6272	AT	—	—	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	C6275	AT	—	—	12/10/2015	1.5	12/10/2015	1.5
	C6278	AT	—	—	12/10/2015	2.5	12/10/2015	2.5
	C6281	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	C6282	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	C7645	AT	—	—	11/3/2015	3.8	11/3/2015	3.8
	C7646	AT	—	—	11/3/2015	5.9	11/3/2015	5.9
	C7647	AT	—	—	11/3/2015	6.4	11/3/2015	6.4

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	C7648	AT	7/27/2015	1.5 (U)	11/3/2015	1.5 (U)	11/3/2015	1.5 (U)
	DD-06-2	AT	—	—	12/10/2015	8.7	12/10/2015	8.7
	DD-06-3	AT	—	—	12/10/2015	4.4	12/10/2015	4.4
	DD-12-2	AT	—	—	12/10/2015	1.5 (U)	12/10/2015	1.5 (U)
	DD-12-4	AT	—	—	12/10/2015	4.9	12/10/2015	4.9
	DD-15-2	AT	—	—	12/10/2015	2.6	12/10/2015	2.6
	DD-15-3	AT	7/27/2015	11.2	12/10/2015	8.4	7/27/2015	11.2
	DD-15-4	AT	—	—	12/10/2015	5.2	12/10/2015	5.2
	DD-16-3	AT	—	—	12/10/2015	2.3	12/10/2015	2.3
	DD-16-4	AT	7/27/2015	8.5	12/10/2015	13	12/10/2015	13
	DD-17-2	AT	—	—	12/10/2015	1.5	12/10/2015	1.5
	DD-17-3	AT	—	—	12/10/2015	3.2	12/10/2015	3.2
	DD-39-1	AT	—	—	12/8/2015	1.5 (U)	1/12/2015	4.5
	DD-41-1	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-41-2	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-41-3	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-42-2	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-42-3	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	DD-42-4	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-43-2	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-43-3	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-44-3	AT	5/12/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-44-4	AT	5/11/2015	1.5 (U)	12/7/2015	1.5 (U)	12/7/2015	1.5 (U)
	DD-49-1	AT	—	—	11/3/2015	5.2	11/3/2015	5.2
	DD-49-2	AT	—	—	11/3/2015	4.9	11/3/2015	4.9
	DD-49-3	AT	7/27/2015	9.9	11/3/2015	16	11/3/2015	16
	DD-49-4	AT	—	—	11/3/2015	13	11/3/2015	13
	DD-50-1	AT	—	—	11/3/2015	12	11/3/2015	12
	DD-50-2	AT	—	—	11/3/2015	19	11/3/2015	19
	DD-50-3	AT	—	—	11/3/2015	17	11/3/2015	17
	DD-50-4	AT	7/27/2015	13	11/3/2015	18	11/3/2015	18
	Redox-1-3.3	AT	5/12/2015	3.5	12/8/2015	1.5 (U)	5/12/2015	3.5
	Redox-1-6.0	AT	5/12/2015	1.5 (U)	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	Redox-2-6.0	AT	5/12/2015	8.1	12/8/2015	8.8	12/8/2015	8.8
	Redox-3-3.3	AT	5/12/2015	1.5 (U)	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	Redox-3-4.6	AT	5/12/2015	1.5 (U)	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)

Table 2-9. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	Redox-4-3.0	AT	5/12/2015	1.5 (U)	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)
	Redox-4-6.0	AT	5/12/2015	1.5 (U)	12/8/2015	1.5 (U)	12/8/2015	1.5 (U)

Notes: If more than one sample was collected on the same date, the maximum result was used.

a. High river stage represents the period from April 15 to July 31. Low river stage represents the period from August 28 to December 31.

— = indicates that the sample was not collected or analysis was not performed
AT = aquifer tube
C = compliance well
Cr(VI) = hexavalent chromium
E = extraction well
I = injection well
ISRM = in situ redox manipulation
M = monitoring well
T = in situ redox manipulation aquifer treatment well
U = undetected (detection limit is listed with qualifier in parentheses)

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
HX	199-H1-1	E	6/4/2015	46	10/5/2015	50	10/5/2015	50
HX	199-H1-2	E	6/4/2015	50	10/5/2015	53	10/5/2015	53
HX	199-H1-25	I/M	7/20/2015	1.7	9/23/2015	12	9/23/2015	12
HX	199-H1-27	I/M	7/20/2015	35.9	9/23/2015	38	9/23/2015	38
HX	199-H1-3	E	—	—	—	—	3/30/2015	1.5

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
HX	199-H1-32	E	6/4/2015	38	—	—	6/4/2015	38
HX	199-H1-33	E	6/4/2015	23	—	—	6/4/2015	23
HX	199-H1-34	E	6/4/2015	9	10/5/2015	29	10/5/2015	29
HX	199-H1-35	E	5/21/2015	6.4	10/5/2015	14	10/5/2015	14
HX	199-H1-36	E	6/4/2015	57	10/5/2015	50	6/4/2015	57
HX	199-H1-37	E	6/4/2015	13	—	—	6/4/2015	13
HX	199-H1-38	E	6/4/2015	18	—	—	6/4/2015	18
HX	199-H1-39	E	6/4/2015	14	—	—	6/4/2015	14
HX	199-H1-4	E	6/4/2015	41	9/8/2015	35	6/4/2015	41
HX	199-H1-40	E	5/4/2015	30	—	—	5/4/2015	30
HX	199-H1-42	E	7/6/2015	42	9/23/2015	84	9/23/2015	84
HX	199-H1-43	E	6/4/2015	24	10/5/2015	38	10/5/2015	38
HX	199-H1-45	E	7/6/2015	38	10/5/2015	62	10/5/2015	62
	199-H1-46	M	6/24/2015	65.8	—	—	6/24/2015	65.8
HX	199-H1-6	M	7/20/2015	1.5 (U)	—	—	2/4/2015	35
	199-H1-7	M	4/28/2015	1.5	12/1/2015	86	12/1/2015	86
HX	199-H3-25	E	6/29/2015	4	10/5/2015	21	10/5/2015	21
HX	199-H3-26	E	6/29/2015	17	9/8/2015	3	6/29/2015	17

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-H3-2A	M	5/29/2015	1.5 (U)	12/3/2015	1.5 (U)	12/3/2015	1.5 (U)
	199-H3-3	M	4/24/2015	3.7	11/2/2015	6.8	2/2/2015	7.8
HX	199-H3-4	E	6/4/2015	16	10/5/2015	13	6/4/2015	16
	199-H3-5	M	4/24/2015	8.6	11/5/2015	20	11/5/2015	20
	199-H3-6	M	4/24/2015	2.1	11/5/2015	1.5 (U)	4/24/2015	2.1
	199-H3-7	M	4/28/2015	1.7	11/5/2015	1.5 (U)	4/28/2015	1.7
	199-H4-10	M	5/29/2015	6.7	12/1/2015	4.7	5/29/2015	6.7
	199-H4-11	M	5/13/2015	7.8	12/3/2015	6.6	5/13/2015	7.8
	199-H4-12A	M	5/4/2015	14.2	12/3/2015	3.6	5/4/2015	14.2
	199-H4-13	M	6/7/2015	4.6	12/3/2015	5.8	2/23/2015	8.9
HX	199-H4-15A	E	7/6/2015	17	10/5/2015	14	2/4/2015	18
	199-H4-15CP	M	—	—	10/14/2015	1.5 (U)	10/14/2015	1.5 (U)
	199-H4-15CQ	M	—	—	10/16/2015	2.9	10/16/2015	2.9
	199-H4-15CR	M	—	—	10/23/2015	7.9	10/23/2015	7.9
	199-H4-16	M	5/4/2015	1.5	11/8/2015	1.5 (U)	11/8/2015	1.5 (U)
HX	199-H4-4	E	7/6/2015	13	—	—	7/6/2015	13
	199-H4-45	M	5/29/2015	2.5	9/17/2015	1.9	2/23/2015	5.1
	199-H4-46	M	5/4/2015	1.5	11/10/2015	1.5 (U)	2/2/2015	1.8

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-H4-49	M	5/13/2015	8.6	11/10/2015	5.7	5/13/2015	8.6
	199-H4-5	C	6/7/2015	1.5 (U)	12/1/2015	2.6	2/26/2015	3.4
	199-H4-6	M	—	—	10/14/2015	1.5 (U)	4/10/2015	2
HX	199-H4-63	E	7/6/2015	11	10/5/2015	12	10/5/2015	12
HX	199-H4-64	E	6/10/2015	7.1	10/5/2015	9	10/5/2015	9
	199-H4-65	M	5/13/2015	17.5	12/1/2015	9.7	5/13/2015	17.5
HX	199-H4-69	E	5/4/2015	8	10/5/2015	4	5/4/2015	8
HX	199-H4-70	E	7/6/2015	6	10/5/2015	2	7/6/2015	6
HX	199-H4-74	E	7/9/2015	26	9/8/2015	37	8/3/2015	43
HX	199-H4-75	E	7/20/2015	54.1	10/5/2015	62	10/5/2015	62
HX	199-H4-76	E	5/4/2015	56	9/23/2015	51	5/4/2015	56
HX	199-H4-77	E	5/4/2015	38	10/5/2015	37	2/4/2015	46
	199-H4-8	M	—	—	12/1/2015	2.1	12/1/2015	2.1
	199-H4-83	M	5/13/2015	5.4	12/3/2015	5.9	12/3/2015	5.9
	199-H4-84	M	—	—	11/19/2015	12	11/19/2015	12
	199-H4-85	M	5/19/2015	18.7	11/19/2015	23	11/19/2015	23
HX	199-H4-86	E	5/7/2015	38.7	10/5/2015	21	5/7/2015	38.7
	199-H4-90	M	6/7/2015	12	9/17/2015	8.7	1/6/2015	16.6

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-H4-91	M	6/7/2015	36.2	12/8/2015	40	12/8/2015	40
	199-H4-92	M	—	—	10/20/2015	19	8/13/2015	22
HX	199-H4-93	E	5/7/2015	55.1	9/14/2015	100	9/14/2015	100
	199-H5-16	M	—	—	10/23/2015	9.6	8/13/2015	11
	199-H5-1A	M	5/7/2015	7	11/13/2015	9.3	11/13/2015	9.3
	199-H6-1	M	5/7/2015	3.6	11/13/2015	2.5	5/7/2015	3.6
HX	199-H6-2	E	7/27/2015	0 (U)	—	—	8/3/2015	5
	199-H6-3	M	5/7/2015	8.6	11/10/2015	7	5/7/2015	8.6
	199-H6-4	M	5/7/2015	11	11/10/2015	3	5/7/2015	11
	199-H6-7	I/M	6/4/2015	6.9	—	—	6/4/2015	6.9
	199-H6-8	I/M	4/16/2015	10.7	—	—	4/16/2015	10.7
	699-100-43B	M	4/24/2015	3.4	10/30/2015	1.5 (U)	4/24/2015	3.4
	699-101-45	M	7/17/2015	14.4	10/30/2015	25	10/30/2015	25
	699-88-41	M	—	—	10/29/2015	11	10/29/2015	11
	699-89-35	M	7/10/2015	8.5	10/23/2015	12	10/23/2015	12
	699-90-37B	M	7/10/2015	4.2	10/29/2015	2.2	7/10/2015	4.2
	699-90-45	M	—	—	10/23/2015	1.5	10/23/2015	1.5
	699-91-46A	M	—	—	10/28/2015	1.5 (U)	10/28/2015	1.5 (U)

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	699-94-41	M	5/19/2015	14.3	11/4/2015	14	2/26/2015	14.5
	699-94-43	M	5/19/2015	30.8	11/4/2015	19	2/26/2015	33.2
	699-95-45	M	5/19/2015	2.4	11/4/2015	1.5 (U)	2/27/2015	6.2
	699-95-45B	I/M	4/28/2015	9.9	—	—	4/28/2015	9.9
	699-96-43	M	—	—	10/29/2015	45	10/29/2015	45
	699-97-41	M	5/29/2015	38.6	11/4/2015	54	8/26/2015	56
	699-97-43B	M	—	—	10/28/2015	41	10/28/2015	41
	699-97-45	M	—	—	10/28/2015	61	10/28/2015	61
	699-97-47B	M	6/15/2015	18.9	10/29/2015	24	10/29/2015	24
	699-97-60	M	—	—	10/29/2015	1.5	8/13/2015	2.8
	699-98-43	M	—	—	10/30/2015	44	10/30/2015	44
	699-98-46	M	5/28/2015	30.4	11/1/2015	37	11/1/2015	37
	699-99-41	M	5/28/2015	2.7	11/4/2015	1.7	5/28/2015	2.7
	699-99-44	M	5/28/2015	37	11/4/2015	32	5/28/2015	37
Aquifer Tubes								
	44-M	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	45-D	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	45-M	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	45-S	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	47-D	AT	—	—	11/23/2015	1.5 (U)	11/23/2015	1.5 (U)
	47-M	AT	—	—	11/23/2015	1.8	11/23/2015	1.8
	48-M	AT	—	—	12/11/2015	6.8	12/11/2015	6.8
	48-S	AT	—	—	12/11/2015	4	12/11/2015	4
	49-D	AT	7/28/2015	3	12/11/2015	4.5	12/11/2015	4.5
	50-M	AT	—	—	11/5/2015	5.6	1/13/2015	8.5
	50-S	AT	7/28/2015	4.2	—	—	1/13/2015	12
	51-D	AT	—	—	10/19/2015	22	10/19/2015	22
	51-M	AT	—	—	10/19/2015	15	10/19/2015	15
	51-S	AT	—	—	10/19/2015	7.3	10/19/2015	7.3
	52-D	AT	—	—	11/5/2015	1.5 (U)	11/5/2015	1.5 (U)
	52-M	AT	—	—	11/5/2015	1.5 (U)	11/5/2015	1.5 (U)
	52-S	AT	—	—	11/5/2015	1.5 (U)	11/5/2015	1.5 (U)
	54-D	AT	—	—	11/5/2015	1.5 (U)	11/5/2015	1.5 (U)
	54-M	AT	—	—	11/5/2015	3	11/5/2015	3
	54-S	AT	—	—	10/5/2015	1.5 (U)	10/5/2015	1.5 (U)
	AT-H-1-D	AT	—	—	12/11/2015	2.1	1/13/2015	6.8

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	AT-H-1-M	AT	7/28/2015	1.5 (U)	12/11/2015	1.5 (U)	12/11/2015	1.5 (U)
	AT-H-1-S	AT	—	—	12/11/2015	1.5 (U)	12/11/2015	1.5 (U)
	AT-H-2-D	AT	—	—	12/11/2015	1.8	12/11/2015	1.8
	AT-H-3-D	AT	—	—	12/11/2015	5.6	12/11/2015	5.6
	AT-H-3-S	AT	—	—	12/11/2015	3.2	12/11/2015	3.2
	C5632	AT	—	—	11/10/2015	1.5 (U)	11/10/2015	1.5 (U)
	C5633	AT	—	—	11/10/2015	5.1	11/10/2015	5.1
	C5634	AT	—	—	11/10/2015	1.5 (U)	11/10/2015	1.5 (U)
	C5635	AT	—	—	11/10/2015	1.5 (U)	11/10/2015	1.5 (U)
	C5636	AT	—	—	11/10/2015	2.5	11/10/2015	2.5
	C5637	AT	—	—	11/10/2015	2.8	11/10/2015	2.8
	C5638	AT	—	—	11/10/2015	6.2	11/10/2015	6.2
	C5641	AT	7/28/2015	6.5	11/10/2015	13	11/10/2015	13
	C5644	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	C5673	AT	—	—	11/10/2015	1.5 (U)	11/10/2015	1.5 (U)
	C5674	AT	—	—	11/10/2015	1.5 (U)	11/10/2015	1.5 (U)
	C5676	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	C5677	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	C5678	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	C5679	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	C5680	AT	—	—	11/12/2015	1.9	11/12/2015	1.9
	C5681	AT	—	—	11/12/2015	1.5 (U)	11/12/2015	1.5 (U)
	C5682	AT	—	—	12/11/2015	1.5 (U)	12/11/2015	1.5 (U)
	C6284	AT	—	—	11/10/2015	2.8	11/10/2015	2.8
	C6285	AT	—	—	11/10/2015	3.8	11/10/2015	3.8
	C6286	AT	—	—	11/10/2015	7.8	11/10/2015	7.8
	C6287	AT	—	—	10/19/2015	4.6	10/19/2015	4.6
	C6288	AT	7/28/2015	5.3	10/19/2015	10	10/19/2015	10
	C6296	AT	—	—	11/23/2015	1.5 (U)	11/23/2015	1.5 (U)
	C6297	AT	—	—	11/23/2015	2.1	11/23/2015	2.1
	C6299	AT	—	—	12/11/2015	1.5 (U)	12/11/2015	1.5 (U)
	C6300	AT	—	—	12/11/2015	1.5 (U)	12/11/2015	1.5 (U)
	C7649	AT	—	—	12/11/2015	1.5 (U)	1/13/2015	8.1
	C7650	AT	7/28/2015	37.8	12/11/2015	18	7/28/2015	37.8

Table 2-10. 2015 Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems

System	Well or Aquifer Tube Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)

Notes: If more than one sample was collected on the same date, the maximum result was used.

a. High river stage represents the period from April 15 to July 31. Low river stage represents the period from August 28 to December 31.

—	=	indicates that the sample was not collected or analysis was not performed	E	=	extraction well
AT	=	aquifer tube	I	=	injection well
C	=	compliance well	M	=	monitoring well
Cr(VI)	=	hexavalent chromium	U	=	undetected (detection limit is listed with qualifier in parentheses)

Table 2-11. 2015 Maximum Cr(VI) Concentrations for 100-H Area and 100-D Area RUM Wells

System	Well Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-D5-134	M	—	—	10/28/2015	2.2	10/28/2015	2.2
	199-D5-141	M	—	—	10/28/2015	1.5 (U)	10/28/2015	1.5 (U)
	199-D8-54B	M	5/29/2015	4.1	12/7/2015	1.5 (U)	5/29/2015	4.1
	199-H2-1	M	5/4/2015	6.4	11/13/2015	23	11/13/2015	23
	199-H3-10	M	5/7/2015	4.4	11/8/2015	2.2	5/7/2015	4.4
HX	199-H3-2C	E	6/10/2015	63.2	10/5/2015	67	8/3/2015	78
HX	199-H3-9	E	5/4/2015	113	10/5/2015	79	5/4/2015	113
HX	199-H4-12C	E	7/6/2015	125	10/5/2015	137	10/5/2015	137

Table 2-11. 2015 Maximum Cr(VI) Concentrations for 100-H Area and 100-D Area RUM Wells

System	Well Name	Well Use	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
	199-H4-15CS	M	—	—	10/23/2015	29	10/23/2015	29
	699-97-43C	M	4/24/2015	1.5	10/28/2015	1.5 (U)	10/28/2015	1.5 (U)
	699-97-45B	M	4/28/2015	3.3	10/28/2015	3.2	4/28/2015	3.3
	699-97-48C	M	4/28/2015	87.9	10/29/2015	120	10/29/2015	120

Notes: If more than one sample was collected on the same date, the maximum result was used.

a. High river stage represents the period from April 15 to July 31. Low river stage represents the period from August 28 to December 31.

— = indicates that the sample was not collected or analysis was not performed

Cr(VI) = hexavalent chromium

E = extraction well

M = monitoring well

U = undetected (detection limit is listed with qualifier in parentheses)

Table 2-12. Comparison of River Protection Assessment Results

Assessed Shoreline Lengths 100-HR-3/100-D	2014	2015	Change from 2014 to 2015
Total length of shoreline adjacent to 100-D Area	2,800 m (9,185 ft)		
Length identified as "protected" Percent of shoreline "protected"	1,500 m (4,920 ft) 54% of shoreline	2,400 m (7,870 ft) 86% of shoreline	Additional 900 m (2,950 ft) of shoreline identified as "protected"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	800 m (2,625 ft) 28% of shoreline	100 m (330 ft) 3% of shoreline	700 m (2,295 ft) of shoreline previously identified as "protected (action may be required)" now identified as "protected"
Length identified as "not protected" Percent of shoreline "not protected"	500 m (1,640 ft) 18% of shoreline	300 m (985 ft) 11% of shoreline	Net change of 200 m (655 ft) of shoreline previously identified as "not protected" now identified as "protected" or "protected (action may be required)"
Assessed Shoreline Lengths 100-HR-3/100-H	**2014**	**2015**	**Change from 2014 to 2015**
Total length of shoreline adjacent to 100-H Area	4,400 m (14,430 ft)		
Length identified as "protected" Percent of shoreline "protected"	2,700 m (8,855 ft) 61% of shoreline	3,100 m (10,175 ft) 71% of shoreline	Additional 400 m (1,315 ft) of shoreline identified as "protected"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	1,200 m (3,935 ft) 27% of shoreline	800 m (2,625 ft) 18% of shoreline	Net change of 400 m (1,310 ft) of shoreline previously identified as "protected (action may be required)" now identified as "protected"
Length identified as "not protected" Percent of shoreline "not protected"	500 m (1,640 ft) 11% of shoreline	500 m (1,640 ft) 11% of shoreline	No net change as "protected" or "protected (action may be required)"

This page intentionally left blank.

Table 2-13. Breakdown of HR-3 P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)																
	1999	2000	2001[a]	2002[b]	2003	2004	2005	2006	2007	2008	2009[c]	2010	2011[d]	2012[e]	2013[f]	2014[e]	2015[g]
Design	—	—	97.7	15.4	8.1	196.1	196.0	55.0	92.0	—	0.0	26.5	—	0.7	—	—	0.0
Treatment system capital construction	—	57.7	(36.1)	750.3	—	496.6	10.0	—	—	—	—	—	—	—	—	—	1,053.2
Project support	265.3	276.7	225.8	309.3	229.8	211.8	722.6	697.6	171.9	169.5	204.7	139.6	11.7	—	0.7	—	0.1
Operations and maintenance	1,650.8	799.1	739.2	816.6	733.7	1,049.5	618.5	891.2	679.6	1,084.8	1,091.8	1,411.5	788.9	42.5	201.6	2.2	29.4
Performance monitoring	—	173.7	219.9	120.0	163.2	120.3	353.0	489.6	219.5	508.5	237.7	240.0	—	—	—	—	0.1
Waste management	—	895.3	424.9	720.1	877.2	501.7	202.2	217.6	434.7[h]	192.2	16.6	75.0	—	3.0	—	—	5.1
Totals	**$1,916**	**$2,203**	**$1,671**	**$2,732**	**$2,012**	**$2,576**	**$2,102**	**$2,351**	**$1,598**	**$1,955**	**$1,551**	**$1,893**	**$801**	**$46**	**$202**	**$2**	**$1,088**

a. 2001 costs were corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

b. 2002 accrual costs were corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

c. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

d. The HR-3 P&T system went into cold-standby status in May 2011.

e. Costs after system shutdown in 2011 are associated with surveillance and maintenance pending decommissioning of the HR-3 P&T facility.

f. Costs for 2013 were associated with disposal of Dowex® (a registered trademark of the Dow Chemical Company, Midland, Michigan) 21K resin.

g. Costs for 2015 are associated with surveillance and maintenance end decommissioning of the HR-3 P&T facility.

h. Additional costs were associated with drilling wastes and resin cleared for shipment and handling.

— = not available

P&T = pump and treat

This page intentionally left blank.

Table 2-14. Breakdown of DR-5 P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)									
	2005	2006	2007	2008	2009[a]	2010	2011[b]	2012[c]	2014[c]	2015[d]
Design	246.9	196.8	100.4	—	3.2	3.4	—	(0.1)	—	0.0
Treatment system capital construction	—	22.2	—	—	—	—	—	—	—	1,053.2
Project support	586.4	370.6	240.3	233.6	204.7	139.6	2.7	—	—	0.1
Operations and maintenance	459.6	605.7	541.3	884.7	1,091.7	919.9	185.4	21.6	9.5	25.6
Performance monitoring	106.2	1.6	11.3	127.1	237.7	240.0	—	—	10.7	0.0
Waste management	28.3	154.7	45.4	23.8	1.7	29.0	—	—	—	5.2
Totals	**$1,427**	**$1,352**	**$939**	**$1,269**	**$1,539**	**$1,332**	**$188**	**$21**	**$20**	**$1,084**

a. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. The DR-5 P&T system went into cold standby in March 2011.

c. Costs after system shutdown in 2011 are associated with ongoing surveillance and maintenance while the facility is in standby. In 2014, the facility was transitioned for use as a well maintenance facility.

d. Costs for 2015 are associated with surveillance and maintenance end decommissioning of the DR-5 P&T facility

— = not available

P&T = pump and treat

Table 2-15. Breakdown of DX P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)						
	2009[a]	2010	2011[b]	2012	2013	2014	2015
Design	2,115.2	1,287.8	100.7	34.3	28.9	5.7	48.4
Treatment system capital construction	5,759.8	16,266.3	—	(3.1)	244.2	565.7	831.2
Project support	495.1	1,236.9	45.7	71.3	186.0	132.4	165.5
Operations and maintenance	—	—	2,979.3	1,566.3	2,186.4	2,029.8	4,322.9
Performance monitoring	—	—	1.8	294.9	125.4	226.6	264.1
Waste management	7.4	9.2	—	0.8	0.0	0.6	423.2
Field studies	—	—	—	—	—	0.4	—

Table 2-15. Breakdown of DX P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)						
	2009[a]	2010	2011[b]	2012	2013	2014	2015
Totals	**$8,377**	**$18,800**	**$3,128**	**$1,965**	**$2,771**	**$2,961**	**$5,675**

a. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. DX P&T construction was completed in December 2010, entered acceptance test procedures, and became fully operational in January 2011.

— = not available

P&T = pump and treat

Table 2-16. Breakdown of HX P&T System Construction Costs

Description	Actual Costs (Dollars × 1,000)						
	2009[a]	2010	2011[b]	2012	2013	2014	2015
Design	896.4	1,047.5	1,079.8	35.9	3.6	6.0	39.2
Treatment system capital construction	214.1	9,354.2	11,316.2	(2.3)	220.0	566.9	708.6
Project support	—	400.2	1,981.4	53.2	179.4	128.7	163.9
Operations and maintenance	—	—	321.2	1,187.4	1,727.6	1,964.6	3,862.8
Performance monitoring	—	—	8.0	189.7	122.7	189.7	221.8
Waste management	—	0.1	—	1.0	—	—	36.8
Field studies	—	—	—	—	—	0.4	—
Totals	**$1,111**	**$10,802**	**$14,707**	**$1,465**	**$2,253**	**$2,856**	**$5,033**

a. Annual reporting has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. HX P&T construction was completed in September 2011, entered acceptance test procedures, and became fully operational in October 2011.

— = not available

P&T = pump and treat

3 100-KR-4 Operable Unit Remediation

This chapter describes the status of interim groundwater remedies and other CERCLA activities for the 100-KR-4 OU. The operational results for the three 100-KR-4 OU P&T systems for 2015 are described, and progress towards remediating the aquifer since P&T startup is summarized.

3.1 Summary of Operable Unit Activities

The 100-KR-4 OU incorporates groundwater contaminated by releases from facilities and waste sites associated with past operation of the KE and KW Reactors (Figure 3-1). The Cr(VI) released from these facilities and waste sites poses a risk to human health and/or the environment and was identified in the interim action ROD (EPA/ROD/R10-96/134) as the primary groundwater COC in this OU. Groundwater co-contaminants identified in this interim remedial action scope are nitrate, tritium, strontium-90, carbon-14, and trichloroethene (TCE).

The interim action ROD for the 100-KR-4 OU (EPA/ROD/R10-96/134) defined the Cr(VI) cleanup goal in groundwater discharging to the Columbia River at the ambient water quality criterion of 11 µg/L. Based in part on the expectation that contaminated groundwater (prior to discharging to the river) is mixed on a 1:1 basis with relatively uncontaminated water within a near-shore mixing zone along the river, attaining less than 22 µg/L of Cr(VI) in the compliance monitoring well network is consistent with achieving this RAO. The ESD for the 100-HR-3 and 100-KR-4 OUs (EPA et al., 2009) reduced the groundwater remediation target to 20 µg/L to meet a revised surface water quality criterion of 10 µg/L. Consequently, a compliance level of 20 µg/L for Cr(VI) in groundwater is currently applied to near-shore and compliance wells along the river. The DWS for total chromium remains at 100 µg/L. Ecology has established a Method B groundwater cleanup level of 48 µg/L for Cr(VI) in accordance with WAC 173-340.

To mitigate risks associated with Cr(VI) contamination in groundwater discharging to the river, three CERCLA interim action IX P&T systems have been installed in the 100-KR-4 OU. All three P&T systems (KR4, KW, and KX) were operational throughout 2015. The KR4 P&T system was the first system installed and began operation in 1997; it was designed to remediate groundwater around the 116-K-2 Trench (Figure 3-2). The KW P&T system was the second system installed and began remediating Cr(VI) in the KW Reactor area in February 2007. The third and newest P&T system, KX, began operation in November 2009. The KX P&T system is used primarily to treat Cr(VI) in groundwater that migrated from the 116-K-2 Trench area toward N Reactor and near the proximal end of the trench near the KE Reactor area. Figure 3-2 shows the extraction and injection wells comprising the well fields for these systems, as well as associated monitoring wells and other monitoring locations. The inferred distribution of Cr(VI) in groundwater in the 100-KR-4 OU vicinity, as well as the inferred groundwater elevation contours for the low and high river-stage periods during 2015, are shown in Figures 3-3 and 3-4, respectively.

Monitoring, data evaluation, and site characterization activities are conducted each year in an ongoing effort to determine the 100-KR-4 OU P&T systems' performance compared to design criteria, whether system design modifications or operating parameters will further optimize performance, and the measurable progress toward achieving plume cleanup and river protection RAOs. This chapter discusses the results of the 2015 100-KR-4 OU P&T evaluation and includes the following:

- Section 3.2 discusses the interim action groundwater remediation activities.
- Section 3.3 provides the remedial action cost summary.

- Sections 3.4 and 3.5 present the conclusions and recommendations, respectively, for the 100-KR-4 OU.

3.1.1 100-KR-4 Operable Unit Pump and Treat Systems

Changes to the 100-KR-4 OU interim action P&T systems during 2015 consisted primarily of constructing additional wells for monitoring, extraction, and injection, as well as realigning selected existing wells for use as extraction wells. These actions were intended to enhance hydraulic plume capture, reduce Cr(VI) plume concentrations, and remove mass from source areas. Changes to the P&T systems are shown in Table 3-1. The locations of the new and realigned wells for 2015 are shown in Chapter 1, Figure 1-7.

3.1.2 Remedial Investigation/Feasibility Study Activities

An RI/FS was conducted to support the final ROD for the 100-K Area in 2010 and 2011. Characterization activities began in 2009 (as described in DOE/RL-2008-46-ADD2) and were implemented through the sampling and analysis plan (SAP) DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*. The RI/FS for the 100-KR-1, 100-KR-2, and 100-KR-4 OUs DOE/RL-2010-97, *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, was submitted as Draft A for regulatory review in September 2011. The U.S. Environmental Protection Agency (EPA) and DOE identified a need for additional characterization beneath the KE Reactor fuel storage basin (FSB) and the 116-KE-3 FSB crib/reverse well to fill a data gap regarding nature and extent of vadose zone contamination around the reactor structures before issuing Rev. 0 of the RI/FS report. These characterization activities, including drilling two exploratory boreholes, collecting and analyzing subsurface soil and groundwater samples, and completing the two boreholes as monitoring wells, were performed during 2015. Contaminated soil and groundwater were observed beneath the two waste sites. A characterization report for this activity is currently being prepared and should be available during CY 2016.

3.2 100-KR-4 Operable Unit Interim Action Activities

This section summarizes the non-RI/FS CERCLA activities for the 100-KR-4 OU during the reporting period, including activities related to operation and performance monitoring of the KR4, KW, and KX P&T systems during 2015. Specific activities and operational performance details for these systems include system configuration changes and availability, contaminant mass removed during operation, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, and waste generation.

3.2.1 KR4 Pump and Treat System

The KR4 P&T system was designed to capture and treat the Cr(VI) plume associated with the 116-K-2 Trench (Figure 3-2). A large volume of reactor cooling water was discharged to the 116-K-1 Crib and subsequently to the 116-K-2 Trench during reactor operations. This water contained Cr(VI) at varying concentrations, up to 600 μg/L. The releases created a large, widespread Cr(VI) plume centered on the trench that extends to the Columbia River and several kilometers inland in all directions. Since startup in 1997, the KR4 P&T system has treated more than 7.91 billion L (2.09 billion gal) of groundwater and has removed 375 kg (826 lb) of Cr(VI). The KR4 P&T system has remediated much of the original plume along the central 116-K-2 Trench to Cr(VI) concentrations less than 20 μg/L; however, substantial contamination remains in the groundwater at either end of the trench and inland areas. Most of the extraction wells of the KR4 P&T system exhibited Cr(VI) concentration below 20 μg/L during 2015, with many wells exhibiting concentrations less than 10 μg/L. Continued operation of the

KR4 P&T system is indicated to provide hydraulic containment of groundwater near the Columbia River at the proximal and distal regions of the trench. This plume dissection has resulted primarily from extracting high-concentration groundwater along the trench and from the effects of injecting treated effluent water into wells located near the middle of the trench with a subsequent low-concentration mound established at that location. The substantial contaminant mass reduction near the central 116-K-2 Trench is reflected in the overall influent concentration decline observed at the treatment system (Figure 3-5). The average influent concentration at the KR4 P&T system was less than 10 µg/L in 2015, ranging from a minimum of 2 µg/L to a maximum of 12 µg/L.

3.2.1.1 KR4 Pump and Treat System Configuration and Changes

The KR4 P&T system (Figure 3-6) was designed to receive and process up to 1,135.6 L/min (300 gal/min). The current system design includes 12 extraction wells and 5 injection wells (Figure 3-2). No changes to the P&T system well network were made in 2015. Since the changeover to ResinTech SIR-700 resin in 2012, no resin changeouts have been required at the KR4 P&T system.

The KR4 P&T system continued to operate in 2015 using SIR-700 chromate-specific IX resin. Process stream pH is measured near the inlet to the IX vessels and before the treated process effluent is discharged. The average influent pH for the KR4 P&T system during 2015 was 6.73 units; the average effluent pH for this system was 6.84 units. No changes in treatment process chemistry were implemented during 2015. Technical evaluation of optimal system pH for influent and effluent discharge is ongoing.

3.2.1.2 KR4 Pump and Treat System Performance

Table 3-2 presents an overview of the operational parameters and total system performance for the KR4 P&T system during 2015. Groundwater was processed at an annual average pumping rate of 1,249 L/min (330 gal/min) during 2015. The average Cr(VI) concentration in the P&T system influent for 2015 was 6.4 µg/L (Figure 3-7) compared to 9.5 µg/L and 11.1 µg/L in 2014 and 2013, respectively. The maximum Cr(VI) concentration observed in the system effluent during 2015 was 2 µg/L, and the average concentration for the reporting period was less than 2 µg/L. Additional operational and system characteristics of the KR4 P&T system for 2015 are summarized as follows:

- A total of 655 million L (173 million gal) of groundwater was treated, and approximately 3.9 kg (8.6 lb) of Cr(VI) were removed.
- Mass removal efficiency was 83 percent, which is less than the 93.7 percent reported in 2014. The decrease in process removal of chromium is related to the decreasing concentration in extracted groundwater and not IX resin effectiveness since the effluent concentration were below detection in over 80 percent of the process samples. The effluent always met the discharge criterion. Since 1997, average annual influent concentrations have been decreasing over time (Figure 3-5).
- Total treatment system uptime was 99.5 percent.

Only one KR4 P&T extraction well, 199-K-144, exhibited Cr(VI) concentrations above the interim remedial action groundwater target concentration of 20 µg/L during at least one sampling event during 2015. The maximum measured Cr(VI) concentration in this extraction well was 27 µg/L in 2015.

Table 3-3 presents the pumping flow rates and total run-time percentage (total flow hours divided by total possible run-time) for each extraction and injection well currently in use for the KR4 P&T system. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping. During 2015, some wells were subject to downtime due to equipment repair and/or maintenance.

The downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for each extraction well. The monthly online availability for the KR4 P&T system for 2015 is illustrated in Figure 3-8.

Other COCs were detected in the effluent from the KR4 P&T system during 2015, including average concentrations of tritium at 5,775 pCi/L, nitrate at 10,850 µg/L, strontium-90 at 2.6 pCi/L, and carbon-14 at 17.3 pCi/L. Total chromium was detected at an average concentration of 1.2 µg/L. All of these effluent contaminant concentrations were less than their respective DWSs. TCE was not analyzed at the KR4 P&T system. These contaminants are unaffected by the SIR-700 resin treatment system and, therefore, pass through the system.

3.2.2 KW Pump and Treat System

The KW P&T system became operational on January 29, 2007, and has treated over 3.6 billion L (942 million gal) of groundwater and removed 238 kg (525 lb) of Cr(VI). This P&T system was installed to address Cr(VI) groundwater contamination in the KW Reactor area (Figure 3-2). The sources of Cr(VI) in the groundwater are historically intentional and UPRs of water treatment chemicals near the 183-KW Head House chemical storage tank farm. Possible UPRs from the pipeline that transferred sodium dichromate solution from the tank farm to the injection point at the clear wells may have contributed to the condition. The KW P&T system includes 11 groundwater extraction wells located downgradient of the head house area and 4 injection wells located around the former tank farm area.

3.2.2.1 KW Pump and Treat System Configuration and Changes

The KW P&T system continued to operate in 2015 using the two-vessel train configuration and SIR-700 resin (Figure 3-9). The pretreatment IX vessel installed in 2014 remained in service to pre-treat groundwater extracted from the well 199-K-205, which had exhibited the highest Cr(VI) concentration during the year, even though observed Cr(VI) concentration in water extracted from well 199-K-205 decreased from 200 µg/L to about 20 µg/L over the course of 2015.

During 2015, the KW P&T system operated under a focused pumping strategy, using eight of the extraction wells at higher pumping rates to remove groundwater along the axis of the Cr(VI) plume generally perpendicular to the river. The two wells located in the highest concentration portion of the plume (i.e., 199-K-173 and 199-K-205) were operated at the highest pumping rates (i.e., 50 and 120 gal/min, respectively).

Process stream pH is measured near the inlet to the IX vessels and before the treated process effluent is discharged from the plant. The average influent pH for the KW P&T system during 2015 was 6.74 units and ranged from 6.56 to 7.06; the average effluent pH for this system was 6.75 units and ranged from 6.65 to 6.93. No changes in treatment process chemistry were implemented during 2015. Technical evaluation of optimal system pH for influent and effluent discharge is ongoing.

3.2.2.2 KW Pump and Treat System Performance

Table 3-4 presents the operational parameters and total system performance overview for 2015 for the KW P&T system. During 2015, the system processed groundwater at an average annual pumping rate of approximately 1,241 L/min (328 gal/min) and operated at overall 99 percent run-time.

The KW P&T system influent concentration exhibited a stepwise increase from about 12 µg/L to about 45 µg/L in March 2015 when the pumping rate at extraction well 199-K-205 increased to 473 L/min (125 gal/min). A clear downward trend in the influent concentration was exhibited from April through the end of 2015 (Figures 3-10 and 3-11). Cr(VI) concentration in the KW P&T influent system gradually decreased from about 45 µg/L in January to about 15 µg/L by the end of 2015. The average influent Cr(VI) concentration for 2015 was 22 µg/L, the same average value observed in 2014.

The Cr(VI) concentration in the KW P&T system effluent remained consistently below the 10 µg/L remedial action objective for river protection during 2015 with an average annual concentration of less than 2 µg/L. The maximum detected Cr(VI) concentration in the KW P&T effluent samples in 2015 was 4 µg/L (Figure 3-10). Five effluent samples were collected for laboratory analysis during the year. Analytical laboratory results were below detection limits for four of the effluent samples (less than 1.5 µg/L); one sample exhibited hexavalent chromium at 1.8 µg/L. These results are consistent with the in-plant measurements. Resin replacement has not been required at the KW P&T system since SIR-700 resin was placed in service in September 2011.

Selected operational and system characteristics of the KW P&T system for 2015 are summarized as follows:

- Overall total system uptime (calculated as the fraction of time the P&T system was in operation) was 99 percent. The monthly online percentages are shown in Figure 3-12. The KW P&T system treatment throughput continued to exceed the original design treatment capacity (Figure 3-12).
- A total of 651 million L (172 million gal) of groundwater was treated 2015, and approximately 17.6 kg (39 lb) of Cr(VI) were removed.
- The average mass removal efficiency was 94.5 percent, similar to that observed in 2014 (Table 3-4; Figure 3-10).

Table 3-5 presents the pumping flow rates and total run-time percentage (total flow hours divided by total possible run-time) for the extraction and injection wells currently active in the KW P&T system. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping. All wells were subject to downtime for repair and/or maintenance. This downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for the individual extraction wells.

Other COCs were detected in effluent from the KW P&T system, including average concentrations of tritium at 1,373 pCi/L, nitrate at 23,033 µg/L, strontium-90 at 2.0 pCi/L, carbon-14 at 450 pCi/L and TCE at 3.0 µg/L. Total chromium was detected at an average concentration of 2.7 µg/L in system effluent. All of these effluent contaminant concentrations were less than their respective DWSs. These contaminants are unaffected by the SIR-700 resin treatment system and, therefore, pass through the system.

3.2.3 KX Pump and Treat System

The KX P&T system (Figure 3-13) was designed to receive and process groundwater at a rate of up to 2,300 L/min (600 gal/min). The system was primarily designed to treat the K North Cr(VI) plume, located between the northern end of the 116-K-2 Trench and the N Reactor fence line. A portion of the Cr(VI) plume downgradient of the KE Reactor, originating near the 183-KE Head House, is also being captured and treated by the KX P&T system. This system began partial operation in November 2008 and was fully operational in early February 2009. Since startup, the system has treated more than 7.4 billion L (1.9 billion gal) of water and removed approximately 223 kg (492 lb) of Cr(VI).

3.2.3.1 KX Pump and Treat System Configuration and Changes

The KX P&T system currently includes 19 extraction wells and 9 injection wells (Figure 3-2). Well 199-K-208 was installed to improve river protection by enhancing Cr(VI) plume capture in the near-river area downgradient of the KE Reactor, as well as to improve mass removal.

During 2015, the KX P&T system continued to operate using the SIR-700 IX resin in the treatment process. The average influent pH for KX P&T system in 2015 was 6.69 units; the average effluent pH (i.e., treated water returned to the aquifer) was 7.01 units. No changes in treatment process chemistry were implemented during 2015. Technical evaluation of optimal system pH for influent and effluent discharge is ongoing.

3.2.3.2 KX Pump and Treat System Performance

Table 3-6 presents an overview of the operational parameters and total system performance for the KX P&T system during 2015. During the year, the KX P&T system processed groundwater at an average pumping rate of approximately 3,038 L/min (803 gal/min). The system operated 99 percent of the time during 2015 (Figure 3-14).

The average influent Cr(VI) concentration for 2015 was 18.4 µg/L, which is about 14 percent lower than observed in 2014. The KX influent Cr(VI) concentrations exhibited variability during 2015, ranging from about nondetect to 25 µg/L (Figure 3-15).

The maximum reported concentration of Cr(VI) in the KX P&T system effluent during 2015 was 3 µg/L. Effluent concentrations were below detection for most of the year and averaged below the estimated 2 µg/L detection limit (i.e., most of the measurements indicated "0"). Additional operational and system parameters for the KX P&T system for 2015 are as follows:

- A total of 1.6 billion L (419 million gal) of groundwater was treated, and approximately 29 kg (63 lb) of Cr(VI) were removed.
- The annual average mass removal efficiency was 93.2 percent (Table 3-6; Figure 3-16).
- Table 3-7 presents the 2015 pumping flow rates and total run-time for the extraction and injection wells currently active in the KX P&T system. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping. During 2015, each well was subject to downtime due to repair and/or maintenance. The downtime is reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.
- Other COCs were detected in the effluent from the KX P&T system, including average concentrations of tritium at 2,487 pCi/L, nitrate at 14,967 µg/L, strontium-90 at 2.5 pCi/L, and carbon-14 at 65.6 pCi/L. Total chromium averaged 3.5 µg/L in the system effluent. As with the other two P&T systems, these concentrations were all less than their corresponding DWSs. These contaminants are unaffected by the SIR-700 resin treatment system and, therefore, pass through the system.

3.2.4 Performance Monitoring

Control of Cr(VI) in groundwater remains the principal objective of the active groundwater interim remedial action at the 100-KR-4 OU. Strontium-90 and tritium are listed in the interim action ROD for the OU (EPA/ROD/R10-96/134) as co-contaminants and are monitored as part of the remedial action. The ROD acknowledges that the interim action remedy does not treat other non-chromium groundwater contaminants. The groundwater COCs identified in the RI/FS report (DOE/RL-2010-97) are chromium (total and hexavalent), nitrate, carbon-14, strontium-90, tritium, and TCE.

Contaminant concentration data are collected each year from 100-KR-4 OU compliance wells, other monitoring and extraction wells, and aquifer tubes within the OU. The data are used to update the status of the plumes and evaluate the effectiveness of ongoing remedial activities. Particular emphasis is given to data collected during the fall of each year, when river levels are low and contaminant flux toward the river is highest. Tables 3-8 through 3-10 depict the highest 2015 concentrations for Cr(VI), tritium, strontium-90, carbon-14, nitrate, and TCE for the 116-K-2 Trench (K North) area, KW Reactor area, and the KE Reactor area, respectively, which are described in the following subsections. This report focuses on evaluating the analytical results for Cr(VI) being remediated through the interim action P&T systems.

Further summary and analysis of the other COCs and contaminants of interest are presented in the annual groundwater monitoring report (DOE/RL-2016-09).

Tables 3-11 through 3-13 present the 2015 maximum concentration for Cr(VI) in the 100-KR-4 OU plume areas at high and low river stages. CERCLA system performance assessment addresses longer term changes in Cr(VI) concentrations at selected monitoring and extraction wells in the 100-KR-4 OU.

Figures 3-3 and 3-4 present Cr(VI) plume maps for 2015 low river stage and high river stage, respectively. Contaminant plume maps in this report are based on average results for samples collected either during the low- or high-river period in 2015 for each well shown. The plume maps, data summary tables, and a summary of notable data observations are presented in the following subsections. Contaminant plume maps were constructed by computer programs using quantile kriging to produce a continuous spatial illustration of the contaminant distribution (described in Chapter 2).

3.2.4.1 River-Stage Effects

Columbia River stage in the Hanford Reach varies daily with controlled release of water from the upstream Priest Rapids Dam and seasonally in response to annual snowmelt in the mountains of the drainage upstream. High river stage in the Hanford Reach of the Columbia River typically occurs in June or July at the peak of the annual freshet. A hydrograph of river stage at 100-K Area is shown in Figure 3-17. River stage transients during 2015 were dramatically different from preceding years. The high river stage was observed to peak in mid-February, at approximately 120.26 m (394.55 ft) amsl at 100-K. From March through the end of August, the river stage was mostly declining due to the drought conditions experienced in the region and the typical distinct peak river stage conditions were not exhibited during June and July. During the period of low river stage (generally during fall, winter, and early spring), groundwater beneath the 100-K Area flows readily toward the Columbia River. Low river stage at 100-K was observed starting at the end of August, which is consistent with previous years. In 2015, the lowest river stage observed was 116.6 m (382.5 ft) amsl, which occurred in early October.

During high river stage, river water may intrude into the aquifer and cause displacement and/or dilution of the aquifer water in the near-shore environment. Based on evaluation of groundwater elevation maps (Figure 3-18), this bank storage condition during 2015 was substantially reduced from that of previous years. Due to increased pumping rates at groundwater extraction wells, particularly those riverward of the distal portion of the 116-K-2 Trench, groundwater gradient reversal near the river appears to have occurred at some locations. In particular, wells 199-K-112A and 199-K-129 exhibited specific conductance measurements consistently below 200 μS/cm during 2015. Specific conductance of less than 140 μS/cm is indicative of river water (i.e., the Columbia River exhibits a relative low dissolved solids load, thus a low specific conductance). Specific conductance of 300 μS/cm (or greater) is typical of groundwater in the former industrial operating area of the 100-KR-4 OU. Thus, a specific conductance of 200 to 300 μS/cm indicates a likely mixing of groundwater with river water. Groundwater-specific conductance was mapped to evaluate the potential for the migration of river water into the aquifer due to capture by extraction wells (Figure 3-19).

3.2.4.2 Hexavalent Chromium Plumes

Several separate Cr(VI) plumes are differentiated by geographic distribution and by the location and nature of probable source areas. The plumes are associated with three general areas: a plume originating at or near the 183-KW Head House and extending toward the river, a plume originating at or near the 183-KE Head House and extending toward the river, and a plume originating at the 116-K-1 Crib and 116-K-2 Trench and extending radially away from those sites. Conditions observed in groundwater at the 183-KE and 183-KW Head Houses (where historical releases included high-concentration sodium dichromate-dihydrate solution) are likely related to continuing contributions from secondary sources remaining in the vadose zone and/or the periodically rewetted zone in those areas. The 116-K-2 Trench received primarily spent reactor cooling water, containing a substantially lower concentration of sodium dichromate. The potential also remains for continuing contributions from secondary source(s) in the vadose zone and periodically rewetted zone in the trench area.

These plumes have been reshaped and/or dissected by operation of the 100-K Area groundwater P&T systems. The P&T operations have also substantially reduced the observed groundwater Cr(VI) concentrations at many locations. The plume near the KW Reactor is being remediated by the KW P&T system. The plume at the KE Reactor is being remediated primarily by the KX P&T system. The Cr(VI) plume associated with the 116-K-1 Crib and 116-K-2 Trench is being remediated by the KX and KR4 P&T systems. Injection wells for the KX and KR4 P&T systems are located inland and to the northeast of the 116-K-1 Crib and 116-K-2 Trench plume. The injection wells place treated groundwater back into the aquifer and, over time, create a body of groundwater within the aquifer that exhibits a very low concentration of Cr(VI). Figures 3-3 and 3-4 show the inferred Cr(VI) plume distribution for 2015 at low and high river stage, respectively.

116-K-2 Trench Area (K North). The northeastern portion of the 116-K-2 Trench plume extends into the 100-NR-2 OU (Figures 3-3 and 3-4). Groundwater sampling during drilling of well 199-N-189, located east of KX extraction well 199-K-182, detected Cr(VI) over the full thickness of the shallow unconfined aquifer, at concentrations ranging from 29 to 39 μg/L in 2011. Sampling of the completed well in 2015 detected Cr(VI) at a concentration of 40 μg/L. Well 199-N-74, located 2 km (1.2 mi) from the end of the trench and farther north than 199-N-189, exhibited Cr(VI) an average concentration of 39.5 μg/L in 2015. The contamination in both locations likely resulted from migration of the plume at the 116-K-2 Trench during the historical discharge period, when the large discharge mound at the trench moved contaminated water radially to the surrounding area. The Cr(VI) concentrations in these 100-N Area wells are consistent with the historical measurement of total chromium in filtered samples (a confident indication of Cr[VI]) in wells in that area over the past 20 years. Management and ultimate disposal of sodium dichromate solutions to wastewater cribs and trenches at the 100-N Area likely contributed to some of the Cr(VI) observed near the 100-N Area; migration of hexavalent chromium away from the 116-K-2 Trench also likely accounts for some of the Cr(VI) observed near the 100-N Area. Operation of the current P&T systems at the 100-K Area does not appear to be affecting the portions of the Cr(VI) plume(s) inland of the 100-N Area.

The upgradient extent of the plume south of the 116-K-2 Trench suggests that considerable mass may remain to be treated. In the northeastern lobe, the plume is bounded inland of well 199-K-182 by historical measurements of less than 2 μg/L at 699-81-58. Monitoring well 199-K-209, which was drilled in 2014, is located inland of the 116-K-2 Trench and east of the northeastern plume lobe. This well provides an inland boundary for the plume in this area, with a maximum Cr(VI) concentrations at 3.2 μg/L. The overall pumping strategy used in this area is being evaluated to determine if the center of mass for each of these higher concentration plume zones should be more directly targeted for remediation. The 116-K-2 Trench chromium plume is being actively remediated by the KR4 and KX P&T systems.

Based on evaluation of groundwater elevation contours inland of the 100-K Area, groundwater in the inland area appears to flow north-northeast away from the 100-K Area under natural gradients.

Table 3-11 provides data collected from 2015 from wells and aquifer tubes associated with the 116-K-2 Trench K North plume. Table 3-8 presents the highest Cr(VI) concentrations from these locations in 2015. Figure 3-20 provides trend charts for Cr(VI) concentrations for monitoring and extraction wells for the KR4 and KX P&T systems in the 116-K-2 Trench K North area.

The remedial performance of the 100-KR-4 P&T systems (i.e., extent and effectiveness of plume capture and reduction in Cr[VI] concentration in groundwater) has been evaluated using Cr(VI) data from selected monitoring locations identified in DOE/RL-2006-75, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump-and-Treat System*. The general effectiveness of the KR4 P&T system in the central section of the 116-K-2 Trench area is evident by the long-term decreasing concentration trends of Cr(VI) in compliance monitoring wells 199-K-117A, 199-K-21, and 199-K-20, which have averaged below 20 μg/L since 2008 (Figure 3-20). In addition, the concentrations in wells 199-K-125A and 199-K-119A have steadily decreased, from about 40 μg/L in 2004 to consistently less than 10 μg/L since 2010 (Figure 3-20; Table 3-11). This likely reflects both the removal of Cr(VI) from the plume segments in this area and the effects of being located on the downgradient side of the large injection mound formed by the effluent returned to the aquifer by the KX and KR4 P&T system injection wells.

The KR4 P&T system extraction/compliance wells 199-K-113A, 199-K-114A, 199-K-115A, 199-K-116A, and 199-K-129 are located downgradient of the northeast section of the 116-K-2 Trench and near the river in the K North plume (Figure 3-20). These wells have historically exhibited a distinct "saw-tooth" pattern of seasonal fluctuation in Cr(VI) concentration, likely resulting from seasonal influence from capture of increasing and decreasing quantities of river water (Figure 3-20). These wells have all shown a general decreasing trend in Cr(VI) and averaged below 10 μg/L for most of 2015.

The decreasing concentration trends observed throughout 2015 for KR4 P&T system monitoring and extraction wells indicate that the P&T system is achieving the interim action objective of protecting the Columbia River along this section of the K North plume (Figures 3-3 and 3-4). Portions of the identified plumes continue to exhibit Cr(VI) concentrations in excess of the interim remedial action target concentration of 20 μg/L, and remedial actions will continue.

The remedial performance of the KX P&T system has been evaluated using 2015 Cr(VI) data (Table 3-11) and long-term concentration trend plots (Figure 3-20). Data was evaluated for the 15 extraction wells for the KX P&T system and associated monitoring wells, including compliance monitoring/extraction wells 199-K-130, 199-K-131, 199-K-146, 199-K-147, 199-K-148, and 199-K-161.

Most of the KX P&T extraction wells currently capture and remediate the plume area between the northern end of the 116-K-2 Trench and the N Reactor fence line (i.e., K North plume). Monitoring wells 199-K-149 and 199-K-150 were formerly the most northeastern extraction wells in the KX P&T system well field (Figure 3-2). The Cr(VI) concentrations in these wells decreased from approximately 80 μg/L in late 2008 to less than 10 μg/L in fall 2010. The decreased concentrations observed in both wells likely reflects upgradient aquifer cleanup, as well as partial capture and recirculation of treated effluent from injection wells 199-K-159 and 199-K-160 (located 150 to 200 m [492 to 656 ft] cross-gradient to the northeast) and possibly from injection well 199-K-164 (located 430 m [1,411 ft] upgradient) (Figure 3-2). The Cr(VI) concentrations in 199-K-149 and 199-K-150 have remained below 10 μg/L since fall 2010 and bound the northern boundary of the northeastern lobe of the K North plume.

Extraction wells 199-K-131, 199-K-148, 199-K-130, and 199-K-147 are located progressively farther to the southwest. These well locations extend across the northeastern plume lobe of the K North plume, approximately 152 to 183 m (500 to 600 ft) upgradient from, and roughly parallel to, the Columbia River shoreline (Figure 3-20). The concentrations in these wells have steadily decreased since system startup. During 2015, all of these wells were below 20 μg/L.

Upgradient extraction well 199-K-152 and monitoring well 199-K-151 have demonstrated very different concentration trends since KX P&T system startup. Well 199-K-152 is located in the core of the northeastern plume lobe. In 2015, 199-K-152 exhibited concentrations ranging from 9 to 37 μg/L (Table 3-11; Figure 3-20). Monitoring well 199-K-151 is located 230 m (755 ft) northeast/cross-gradient of extraction well 199-K-152. In September 2008, prior to startup of the KX P&T system, the concentration of Cr(VI) in this well was 75.5 μg/L. After startup, the concentrations in monitoring well 199-K-151 rapidly declined, reaching approximately 10 μg/L by early 2011. Concentrations continued to decline and were less than 10 μg/L in 2015.

Chromium concentrations at well 199-K-182, the farthest upgradient well in this plume segment, continued the downward trend from previous years; however, concentrations ranged from 18 to 34 μg/L during 2015. This well was modified in 2014 to increase the diameter of the extracted water conveyance line, which resulted in an increased pumping rate capability at the well. In addition, as part of the RPO process in CY 2015, a larger pump will be installed in this well to increase pumping from approximately 151 to 303 L/min (40 to 80 gal/min) in order to increase mass recovery.

Well 199-N-189, located northeast of 199-K-182, is in the same plume segment. Sampling during drilling in 2011 detected Cr(VI) concentrations above 30 μg/L at sample intervals throughout the aquifer thickness. This well exhibited 40 μg/L Cr(VI) concentration in 2015. Well 199-N-189 is proposed for future realignment as an extraction well to the KX P&T system.

The concentration trends described for extraction wells 199-K-131, 199-K-148, 199-K-130, and 199-K-147 and the nearby monitoring wells suggest that injection of large volumes of treated effluent into 199-K-159, 199-K-160, and 199-K-164 (Figures 3-3 and 3-4) continues to shift the northeastern lobe of the K North plume further to the southwest.

Other KX P&T system extraction wells are located in the southwestern plume lobe of the K North plume (Figure 3-20). Extraction wells 199-K-146 and 199-K-161 are closer to the river than 199-K-153, 199-K-154, and 199-K-163. The Cr(VI) concentrations in well 199-K-146 remained below 10 μg/L for all of 2015, while well 199-K-163 continued the trend of intermittent increases to more than 30 μg/L during 2015. Concentrations in 2015 at inland wells 199-K-153, 199-K-154, and 199-K-163 continued to decline, with 199-K-153 and 199-K-163 at or below 20 μg/L, and 199-K-154 was consistently higher, with an annual average concentration of 43 μg/L.

Monitoring wells 199-K-22 and 199-K-37 are located between upgradient extraction wells 199-K-154 and 199-K-163 and downgradient of extraction wells 199-K-146 and 199-K-161. The Cr(VI) concentration in 199-K-22 declined, ending at 21 μg/L by November 2015. At monitoring well 199-K-37, cross-gradient of the higher concentration area defined by monitoring well 199-K-22, concentrations increased to 30 μg/L by November 2015.

KW Reactor Area. The KW Reactor area Cr(VI) plume is located near the KW Reactor, supporting water treatment facilities, and associated waste sites (Figures 3-3 and 3-4). The plume apparently originated with releases of concentrated sodium dichromate solutions near the 183-KW Head House and chemical storage tank farm. The KW Reactor area plume has been monitored since the early 1990s, when many of the CERCLA monitoring wells were initially installed. The KW P&T system, initially consisting of four extraction wells and two injection wells, became operational in January 2007 to remediate this plume after elevated Cr(VI) concentrations were detected in aquifer tube AT-K-1-D. The upgradient edge of the plume is controlled by the presence of injection wells 199-K-175, 199-K-174, 199-K-158, and 199-K-206. The plume does not extend inland past well 199-K-175, which exhibited concentrations below 10 µg/L when the well was sampled before conversion to an injection well.

Table 3-12 presents the Cr(VI) concentrations for wells and aquifer tubes for monitoring the KW Reactor area plume during 2015 and includes the maximum concentration by river stage for comparison. Table 3-9 presents the highest Cr(VI) concentrations, as well as other co-contaminants, from these locations in 2015. The findings and observations based on the results presented in Tables 3-9 and 3-12 are summarized below:

- Extraction well 199-K-205, in the 183-KW Head House vicinity, exhibits the highest Cr(VI) concentration in the KW Reactor area. During 2015, measured Cr(VI) concentration declined from 195 to 19 µg/L.
- The highest concentrations in the plume are located in the upgradient section of the plume that generally extends from the reactor to the former 183.1-W Head House (Figure 3-3). This plume includes wells 199-K-137 and 199-K-165 (Figure 3-21), which historically had Cr(VI) concentrations of 1,390 and 2,530 µg/L, respectively. Concentrations in these wells by late 2015 remained below 20 µg/L (Table 3-12). The concentration in nearby extraction well 199-K-166 was less than 10 µg/L for most of 2015.
- Cr(VI) concentrations in well 199-K-173 decreased from 30 µg/L in January 2015 to 8 µg/L in December 2015. This well is located upgradient of extraction well 199-K-165 and northeast of injection well 199-K-158. The high concentrations historically observed at this location (e.g., greater than 900 µg/L in 2010) likely resulted from downgradient migration of the high-concentration portion of the plume from the head house area near well 199-K-205. Well 199-K-173 continued operating as an extraction well during 2015.

The remedial performance of the KW P&T system has been evaluated using Cr(VI) data from 2015 (Table 3-12) and the long-term concentration trends for selected KW P&T system monitoring locations (Figure 3-21).

Extraction wells 199-K-132, 199-K-138, and 199-K-196 are located downgradient of the KW Reactor, near the leading edge of the KW Reactor area plume. Since startup of the KW P&T system, Cr(VI) concentrations in these wells have steadily declined (Figure 3-21) and remained between 6 and 16 µg/L during 2015. Aquifer tube AT-K-1-D, which exhibited Cr(VI) as high as 44 µg/L in 2005, exhibited no detectable Cr(VI) during 2015.

Inland extraction wells 199-K-168, 199-K-139, and 199-K-140 each exhibited Cr(VI) concentrations of less than 20 µg/L during 2015 (Figure 3-21; Table 3-12) except for a single spike in well 199-K-140 up to 25 µg/L.

KE Reactor Area and 116-K-2 Trench (KR4 Plume)

The KE Reactor area plume is currently being remediated by KX P&T system extraction wells 199-K-141, 199-K-178, and 199-K-181, and 199-K-210. The plume segment inferred to be east of the reactor is addressed by downgradient extraction wells 199-K-144 and 199-K-145 of the KR4 P&T system. The plume has been monitored since the early 1990s, when several CERCLA monitoring wells were installed to characterize potential groundwater contamination in the area. The source of plume segments in this area is attributed to a combination of localized spills or leaks of highly concentrated sodium dichromate solution associated with the KE Reactor water treatment facilities and the large plume created by mounding around the 116-K-2 Trench (caused by historical release of cooling water to the trench). Based on examination of inferred groundwater gradients in this area and the geochemical characteristics of groundwater at selected wells, the current chromium plume near the KE Reactor appears to represent conditions related to at least two different source areas.

Well 199-K-36 (located near the former 183-KE Head House) exhibited 154 µg/L Cr(VI), which indicates the potential for continuing contribution from the vadose zone in that location. Well 199-K-188, located just upgradient of well 199-K-36, exhibited concentrations of 20 µg/L or less, suggesting that the plume does not extend much inland of that location. KX P&T system extraction well 199-K-220, located near and downgradient of 199-K-36, exhibited Cr(VI) concentrations ranging from 12 to 27 µg/L in 2015.

Table 3-13 provides data from 2015 collected from wells and aquifer tubes associated with the KE Reactor area and 116-K-2 Trench KR4 plume. Table 3-10 presents the highest Cr(VI) concentrations in 2015 from these locations. Figure 3-21 provides trend charts for Cr(VI) concentrations for monitoring and extraction wells for the KR4 and KX P&T systems in the plume area. The remedial performance of the KX and KR4 P&T systems for the KE Reactor area and 116-K-2 Trench KR4 plume (i.e., extent and effectiveness of plume capture and reduction in Cr[VI] concentration in groundwater) have been evaluated using Cr(VI) data from 2015 (Table 3-13). Compliance well 199-K-18 is located in the KR4 plume, near the head end of the 116-K-2 Trench (Figures 3-3 and 3-21), and the Cr(VI) concentrations in this well continued at less than 10 µg/L during 2015.

Although aquifer tubes are not compliance points for treatment system performance, samples collected from these tubes are helpful to locate areas where Cr(VI) may be discharging to the Columbia River. Aquifer tube cluster AT-K-3-S/M/D is located downgradient of monitoring well 199-K-18 and extraction wells 199-K-162, 199-K-145, 199-K-198, and 199-K-199. This aquifer tube group has had concentrations ranging as high as 85 µg/L since it was first sampled in 2004 (Figure 3-21). During 2015, these three aquifer tubes exhibited Cr(VI) concentrations between 8 and 36 µg/L. It is currently not clear what is causing the persistence of Cr(VI) in these aquifer tubes when all downgradient extraction wells have decreased below 10 µg/L. It is possible that a zone of aquifer stagnation has been generated due to increased pumping at five extraction wells; alternatively, a secondary source may be present in the area. Other notable observations from the 2015 data are presented in Tables 3-10 and 3-13 and illustrated in Figure 3-21, including the following:

- The maximum Cr(VI) concentration in the KE Reactor plume was 348 µg/L in well 199-K-111A. Cr(VI) at 199-K-111A appears to be related to migration of chromium from the vicinity of the 116-K-2 Trench and/or the 118-K-1 Burial Ground. Concentrations at cross-gradient monitoring well 199-K-207 had Cr(VI) ranged 90 to 130 µg/L in 2015.

- Operation of extraction well 199-K-210, located inland of aquifer tubes C6246 and C6247, appears to be capturing Cr(VI) that has caused persistent exceedances at these aquifer tubes since 2011.

- Cr(VI) concentrations have decreased in the core of the plume downgradient of the KE Reactor. However, the upgradient plume around well 199-K-36 is likely connected to the main KE Reactor plume originating near the former 183-KE Head House.

- Well 199-K-141, a KX extraction well located downgradient of the KE Reactor and FSB, exhibited decreasing Cr(VI) concentration, but continued to exhibit elevated strontium-90 concentration during 2015. This well is also located on the downgradient edge of the inferred high-concentration strontium-90 plume originating at the 116-KE-3 FSB crib and is apparently capturing part of that plume. Strontium-90 in 199-K-141 was variable during 2015 (between 45 and 64 pCi/L).

3.2.4.3 Other Contaminants of Concern

The interim remedial action for groundwater contamination at the 100-KR-4 OU is directed toward control of Cr(VI). Other constituents present in groundwater within this OU identified as COCs in DOE/RL-2010-97, include the following:

- Nitrate
- TCE
- Strontium-90
- Carbon-14
- Tritium
- Chromium (as total chromium)

These COCs are present in the groundwater being treated for Cr(VI) at varying concentrations and are not subject to a remedial action decision at this time. The releases that caused the contamination by these COCs are generally not coincidental with the sources for the Cr(VI) (except for total chromium, which is present as Cr[VI]). The concentrations of the COCs observed in groundwater range from only slightly greater than DWSs (e.g., TCE at concentrations less than 9 µg/L versus the DWS of 5 µg/L), to substantially exceeding the standards (e.g., carbon-14 at over 20,000 pCi/L compared to the single-nuclide DWS equivalent of 2,000 pCi/L, and strontium-90 at greater than 12,000 pCi/L compared to the single-nuclide DWS equivalent of 8 pCi/L). The occurrence and distribution of COCs in groundwater at the 100-KR-4 OU are described in detail in DOE/RL-2016-09.

The non-chromium COC plumes are variably captured by the Cr(VI) P&T systems. None of these other COCs is treated by the existing interim remedial action P&T systems, and the captured COCs pass unaffected through the systems to be returned to the aquifer at the injection wells. This results in the potential for relocation of COCs into portions of the aquifer where they did not originally exist, or at concentrations different from the pre-injection concentration.

Four of the additional COCs (i.e., TCE, strontium-90, carbon-14, and tritium) are currently found in conditions that may ultimately affect the interim action P&T operations, as described in the following discussion.

Trichloroethene. By the end of CY 2015, TCE exceeded the 5 µg/L DWS in only two wells downgradient of the KW Reactor: 199-K-185 and 199-K-190 (7.2 and 6.5 µg/L, respectively). The historical maximum observed concentration of TCE was about 40 µg/L, although the actual monitoring history is short and a specific primary source for the material has not been identified. The plume exceeding 5 µg/L has been substantially diminished in size during operation of the KW P&T system. The treatment system effluent at the KW P&T system during 2015 continued to contain TCE at about 3.2 µg/L. This has resulted in the evolution of a plume of TCE in the upgradient portion of the KW chromium plume area that currently exhibits TCE at between 3.2 and 4.8 µg/L and extends from the three inland KW injection wells to the monitoring locations near the river. This condition will continue to be monitored.

Strontium-90. Strontium-90 is present in groundwater at concentrations exceeding the 8 pCi/L DWS at several locations within the 100-KR-4 OU. The primary locations of concern for strontium-90 in groundwater are downgradient of the 116-KW-2 FSB crib/reverse well, downgradient of the former 105-KE FSB and 116-KE-3 FSB crib/reverse well, and at multiple locations beneath and downgradient of the 116-K-2 Trench. Of particular interest for the P&T systems is the high-concentration strontium-90 plume located downgradient of the former 105-KE FSB and 116-KE-3 FSB crib, near the KE Reactor.

The maximum strontium-90 concentration in groundwater in this area is estimated at greater than 10,000 pCi/L. KX P&T extraction well 199-K-141 has continued to exhibit increasing strontium-90 concentrations. The concentration was below detection limits prior to start of extraction and increased steadily to 55 pCi/L at the end of 2015. This well location is inferred to be on the leading edge of the strontium-90 plume migrating riverward from the area of the former 105-KE FSB. Strontium-90 extracted by well 199-K-141 provides a measureable contribution of strontium-90 to the KX process stream, with an effluent concentration of 2.4 pCi/L in 2015. This condition will be monitored for potential effects on P&T operation, which is currently focused on Cr(VI) removal.

Carbon-14. Carbon-14 in groundwater in 100-KR-4 OU originated from historical discharges of reactor gas dryer regeneration condensate to the 116-KE-1 and 116-KW-1 Gas Condensate Cribs. Five wells in the KW Reactor area exhibited concentrations above 2,000 pCi/L in 2015 (199-K-106A, 199-K-34, 199-K-139, 199-K-132, and 199-K-204). These wells are located downgradient of the historical release site at the 116-KW-1 Crib. Extraction well 199-K-132 (which was in standby mode for most of 2015) exhibited a substantial increase in carbon-14 concentration in mid-2015 with a measured concentration of 10,900 pCi/L. The increase in carbon-14 was accompanied by substantial increases in nitrate (to 75.3 mg/L) and tritium (to 12,900 pCi/L). These observations indicated the apparent migration of contamination originating at the 116-KW-1 Gas Condensate Crib. Carbon-14 contamination in groundwater continued to be observed as widely distributed over the KW Reactor vicinity at concentrations below 1,000 pCi/L.

A lower concentration carbon-14 plume exists in the KE Reactor area. The plume was formerly defined by wells 199-K-29 and 199-K-30, which have been decommissioned. In 2010, 199-K-29 and 199-K-30 had maximum concentrations of 3,120 and 6,900 pCi/L, respectively, which are above the DWS. These wells monitored conditions downgradient of the 116-KE-1 Crib waste site. As with conditions near the KW Reactor, the carbon-14 plume at the KE Reactor area appears to be migrating downgradient away from the source area. Newly drilled monitoring wells 199-K-221 and 199-K-222, located downgradient of the 105-KE Reactor, exhibited maximum concentrations of carbon-14 of 3,320 and 4,830 pCi/L, respectively. Well 199-K-202 exhibited a concentration of about 2,000 pCi/L in 2015. Well 199-K-203, located riverward of the 116-KE-1 Crib, exhibited carbon-14 at less than 100 pCi/L in monitoring samples collected during 2015. Well 199-K-189, located between these two wells exhibited a concentration of about 3,000 pCi/L during 2015 and has shown an increasing trend. Carbon-14 concentrations will continue to be monitored.

Tritium. Tritium is found in groundwater at multiple locations, with the primary source areas at the 100-K Area being the 116-KE-1 Crib, 116-KW-1 Crib, and 118-K-1 Burial Ground. The highest concentrations of tritium are currently observed in wells downgradient of these source areas. During 2015, tritium concentration observed in well 199-K-111A increased to more than 64,000 pCi/L. Well 199-K-207, located upgradient of 199-K-111A and within the footprint of the former 118-K-1 Burial Ground, exhibited a maximum tritium concentration of 935,000 pCi/L during 2015. This was a substantial increase from the maximum of 414,000 pCi/L observed during drilling in 2014. KX P&T extraction well 199-K-208 exhibited tritium at 271,000 pCi/L in January 2015 during drilling, but declined to about 10,000 pCi/L during extraction operation in 2015. The concentrations at KW extraction well 199-K-132 increased to greater than 10,000 pCi/L in 2015. Tritium concentrations will continue to be monitored.

3.2.5 Hydraulic Monitoring

Hydraulic monitoring (i.e., water-level monitoring) is performed to evaluate the effect of the P&T systems on the water table and to evaluate groundwater flow direction and gradient. The hydraulic effects of the P&T systems are superimposed on seasonal fluctuations in the river levels and inland groundwater elevation to evaluate the effectiveness of providing hydraulic containment and capture of Cr(VI) plumes.

Groundwater elevation is measured manually during regularly scheduled groundwater sampling events, during focused events to collect elevation measurements from many wells over a short period of time, and in selected wells by automated data-logging pressure transducers placed in the wells (AWLN). The 100-K Area AWLN system was refurbished and expanded during 2014, and 49 stations are operating in and around the 100-KR-4 OU as of the end of CY 2015. Additional localized dynamic water level data are collected at each of the P&T extraction and injection wells operating within the 100-K Area. All of the available data are used, where applicable, to assemble the groundwater elevation maps (Figures 3-3, 3-4, and 3-19).

Under natural gradient conditions, groundwater generally flows to the north and northwest toward the Columbia River beneath the 100-KR-4 OU. Hydraulic effects of the P&T systems at the 100-KR-4 OU (i.e., the formation of depressions at extraction wells and mounds at injection locations) are superimposed onto these regional flow patterns. As shown in Figure 3-18, a substantial area of groundwater depression was observed during 2015 from the near-river area of 105-KE Reactor and extending to the distal end of the 116-K-2 Trench. This depression is interrupted near the mid-point of the 116-K-2 Trench by the inferred extension of the recharge mound associated with the 100-KR-4 and 100-KX P&T system injection mounds. The inferred water table is consistent with the observation that operation of the P&T systems is providing groundwater capture and resulting in river protection, along the 100-K Area river shore environs.

The effects of seasonal changes in river stage (and water table elevation) on contaminant concentrations in the aquifer and treatment system performance are discussed in Section 3.2.6. River stage behavior was atypical during 2015, with the absolute peak river stage observed in February 2015. The river stage then remained slightly elevated through the summer before declining to typical seasonal low levels in September, without exhibiting the typical high river stage in June and/or July (Figure 3-17).

During high river-stage periods, the local groundwater gradient magnitude is reduced near the river; the area very near the river may actually exhibit a flow direction reversal, with river water intruding slowly into the aquifer (i.e., seasonal bank storage). In addition, this change (i.e., increased elevation) of the boundary condition causes the groundwater inland of the river to backup during high river stage, thus creating the seasonal increase in groundwater elevation typically observed inland of the river. As the river stage declines following the seasonal freshet, the boundary condition again adjusts, the groundwater gradient steepens toward the river, and velocity increases. This condition continues until the groundwater head again equilibrates with the low river-stage condition. Seasonal groundwater elevation transients are observed up to several kilometers from the river as the water table and river stage equilibrate, although the magnitude of the increase progressively decreases with distance from the river. Figure 3-18 presents a groundwater contour map of the area, which was developed using concurrent measurements collected in March 2015 (near the 2015 maximum river-stage period). Groundwater elevation at the 100-KR-4 OU did not exhibit a substantial seasonal elevation transient during 2015. Long-term groundwater flow near the 100-K Area remains toward the Columbia River.

3.2.6 Hydraulic Containment

Hydraulic containment of the contaminant plumes is an essential element of the performance of P&T remediation in the 100-KR-4 OU. In general, hydraulic containment of the Cr(VI) plume segments in the 100-KR-4 OU is effective. This section presents a comparison of the estimated extent of hydraulic containment for the three 100-KR-4 OU P&T systems with the estimated extent of chromium contamination in groundwater. The assessment is based upon a joint evaluation of groundwater level, pumping rate (extraction and injection), and water quality data. The extent of hydraulic containment is estimated using two methods:

- Water-level mapping using an extension of the hybrid universal kriging/analytic element method technique (detailed in SGW-42305)
- Groundwater modeling using the 100 Area groundwater model (documented in SGW-46279)

In each case, the estimated extent of hydraulic containment is depicted using a CFM. The CFM constructed using the water-level mapping technique is referred to as an ICFM, whereas the CFM constructed using the 100 Area groundwater model is referred to as an SCFM. In each case, the CFM depicts the frequency with which particles representing mobile groundwater and contaminants are moving toward extraction wells, calculated over a series of mapped or simulated groundwater levels that represent conditions throughout the year. A frequency of 1.0 indicates that groundwater in the area is hydraulically contained under all conditions encountered during the period (i.e., groundwater is always moving toward extraction wells). A frequency of zero indicates that groundwater in the area was not hydraulically contained under any conditions encountered during the period (i.e., was at no time during the period moving toward extraction wells). Intermediate frequencies indicate that the groundwater was contained under some, but not all, conditions.

Water-level mapping using the ICFM approach was completed using monthly averaged groundwater elevations, pumping rates, and stage of the Columbia River, which resulted in 12 water-level maps encompassing the River Corridor, and correspondingly, 12 individual depictions of the extent of hydraulic containment for use in constructing an ICFM. Groundwater modeling using the 100 Area groundwater model was completed using monthly average pumping rates, stage of the Columbia River, and other time-varying boundary conditions. This resulted in 12 simulated groundwater level and flow fields, and correspondingly 12 individual depictions of the extent of hydraulic containment for use in constructing an SCFM.

The ICFM and SCFM are collective estimates for the monitoring period; emphasis is placed on regions of high frequency and on comparing areas where the ICFM and SCFM are similar or where they differ. Where the ICFM and SCFM are similar, confidence is relatively high that containment is being achieved (where both maps suggest that containment is achieved) or is weak or it is not being achieved (where both maps suggest that containment is not achieved or, in most cases, where capture frequencies are very low). Where the ICFM and SCFM differ substantially, confidence is lower in the assessment of containment because one method suggests that containment is being achieved whereas the other method suggests either that containment is not being achieved or that it is weak.

Figures 3-22(a) to (f) compare the estimated extent of hydraulic containment and the estimated extent of chromium contamination in groundwater for both high and low river-stage conditions for the 100-K Area as follows:

- Figure 3-22(a) and Figure 3-22(b) depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 3-22(c) and Figure 3-22(d) depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 3-22(e) depicts the groundwater flow lines from particle tracking to estimate the aquifer capture zone of the 100-KR-4 OU P&T systems over a 10-year period.

- Figure 3-22(f) overlays the capture flow lines with the chromium plume contours for low river-stage conditions.

ECF-HANFORD-16-0060 presents details on the specific calculations used to produce these figures, including updates to and implementation of the 100 Area groundwater model, the methodology for water-level mapping, and the development of the ICFM and SCFM.

3.2.7 River Protection Evaluation

The river protection status of conditions at 100-KR-4 OU is based on assessment of the hydraulic effects of operation of the remedial action systems, along with evaluation of changes in the discharge boundary head conditions associated with the Columbia River and the inferred distribution of Cr(VI) in groundwater. Both a quantitative and a qualitative approach are used for this assessment. The assessment indicates that the river protection status improved in 2015 over the assessment for 2014.

This subsection describes the river protection evaluation process and presents the results of the 2015 analysis. SGW-54209 describes a method for evaluating progress toward attaining RAO #1, referred to as the "river protection objective." Since RAO #1 emphasizes protection of aquatic receptors, the river protection objective focuses on the performance of P&T (and other remedies) to protect the Columbia River from further discharges of dissolved chromium from inland at concentrations above 10 µg/L. Use of this standard is consistent with Tri-Party Agreement (Ecology et al., 1989) Milestone M-016-110-T01. ECF-HANFORD-12-0078 demonstrates the methods described in SGW-54209 for evaluating the progress toward attainment of the river protection objective using data obtained during (or prior to) 2011.

Assessment of progress toward attaining the river protection objective for 2015 is presented in Figures 3-23(a) and (b). The technical methods and process that were used to complete the calculations necessary to prepare this figure are detailed in SGW-54209. ECF-HANFORD-16-0060 presents details on the specific calculations that produced the figures for 2015. The results of contaminant standard and trend tests described in SGW-54209 to identify low-, moderate-, and high-concern wells are presented in Figures 3-23(a) and (b) using the following symbols:

Low-Concern Wells			**High-Concern Wells**			**Moderate-Concern Wells**		
Symbol	**Standard**	**Trend**	**Symbol**	**Standard**	**Trend**	**Symbol**	**Standard**	**Trend**
▼	Less than	Down	▲	Exceed	Up	△	Less than	Up
■	Less than	None	■	Exceed	None	▽	Exceed	Down
●	Less than	NSD	●	Exceed	NSD			

NSD = not sufficient data to calculate

Shoreline lengths are calculated and reported in increments of 100 m (328 ft); the results of the assessment are presented in these figures as color-filled circles of diameter equal to 100 m (328 ft). The color fill of each circle indicates the relative river protection objective status (i.e., green = protected; yellow = protected, but action may be required to ensure long-term protectiveness; and red = not protected). The following symbols depict the results of the river protection evaluation:

River Protection Objective - Status

Protected Protected (Action May Be Required) Not Protected

Figures 3-23(a) and (b) depict the results of assessing progress toward attaining the river protection objective for chromium in the 100-K Area. Figure 3-23(a) depicts the results of the quantitative evaluation of the objective, which is determined based upon overlay and quantitative comparison of the extent of chromium contamination and the extent of hydraulic containment. Figure 3-23(b) depicts the results of the qualitative evaluation of the objective, which is based upon the quantitative evaluation but also considers more qualitative considerations (e.g., the duration and magnitude of hydraulic gradients along the shoreline). Based on these calculations, the river protection evaluation for the 100-K Area is as follows (note that all lengths are rounded to the nearest 5 m [16 ft]):

- Total length of shoreline adjacent to the 100-K Area: 4,000 m (13,120 ft)
- Length identified as protected: 3,600 m (11,810 ft)
- Length identified as protected (action may be required): 300 m (980 ft)
- Length identified as not protected: 100 m (330 ft)

The results of the qualitative river protection evaluations for the 100-K Area for 2015 are compared to those presented for 2014 in DOE/RL-2015-05. Table 3-14 provides a comparison of the river protection evaluation for 2014 and 2015.

The effect of river-stage fluctuations on groundwater flow, combined with the aquifer response to pumping, resulted in qualitative evaluations of the river protection objective for 2015 that indicate improved system performance compared to 2014.

Quantitative evaluations of the river protection objective provide conservative assessment of shoreline protection; qualitative evaluations for 2015 incorporate the transient effects of hydraulic capture. The CFMs describe the aggregate fate of particles, under an ensemble of steady-state conditions, each reflecting a snapshot of hydraulic gradient magnitude and direction due to pumping and river stage. As a result, CFMs only indicate the relative strength of hydraulic containment and not a depiction of the actual transient hydraulic capture patterns. CFMs provide an effective metric to evaluate the relative strength of the capture zone, but they should not be considered an absolute indicator of hydraulic containment success or failure. Even during months of steeper hydraulic gradients, groundwater flow velocities result in actual plume migration expected to occur over very short distances. Relative dissipation of hydraulic gradient magnitude in subsequent months results in even slower plume migration and transient hydraulic containment. Capture can, and does, occur in areas where the CFMs indicate relatively low capture frequency. Comparison of the chromium plume depictions for 2014 and 2015 indicates an increased number of shoreline segments in 2015 where chromium concentrations are below the aquatic standard despite the prolonged periods of low river stage. Acknowledgement of these processes is reflected on the qualitative evaluation results.

3.2.8 Comparison of Simulated to Measured Contaminant Mass Recovery

Comparison of the ICFM and SCFM provides comparative depiction of the hydraulic simulation capabilities of the flow component of the 100 Area groundwater model. A similar qualitative comparison can be made for the transport component of the 100 Area groundwater model by comparing simulated and measured rates of contaminant mass recovery.

Figure 3-24 presents a comparison of monthly and cumulative mass of chromium recovered throughout the 100-K Area at each of the KX, KW, and KR4 P&T systems for 2015, as determined using actual influent concentrations and flow rates, versus the mass recovery simulated using the 100 Area groundwater model. For this simulation, the initial distribution of chromium in groundwater was assumed to be the low river-stage depiction of chromium for 2014, as presented in ECF-HANFORD-15-0003.

The pattern of correspondence between the model and the measured data, which varies by system, is fairly well reflected in the model results presented in ECF-HANFORD-16-0060. In each case, there are system-specific and systematic conditions that might lead to differences between the simulated and measured values. ECF-HANFORD-16-0060 presents graphs comparing the simulated and measured mass recovery at each individual extraction well for each P&T system.

For the KW P&T system, the model predicted mass recovery early in the year is well correlated to the measured mass recovery. The model under-predicts mass recovery after that, which is primarily due to mass recovered at well 199-K-205. Influent concentrations at that well ranged between about 200 and 40 μg/L during the year. This suggests that the extent of the high-concentration zone near that well, as well as high-concentration distribution in the same area, were underestimated in the fall 2014 plume, which was used as the initial condition in the simulation. In addition, the concentration distribution downgradient of 199-K-205 also appears to be underestimated in that plume, given that mass recovery at extraction wells 199-K-173, 199-K-137, and 199-K-168/199-K-140 is greater than what the simulated results suggest.

The model under-predicts the measured mass recovery in the KR4 P&T system early in the year, but the gap between measured and simulated mass recovery closes up with time. However, these differences are rather small and reflect the cumulative effect of influent concentrations at the extraction wells of about and mostly below 10 μg/L. Only at well 199-K-144 are concentrations consistently above 20 μg/L. and the model under-predicts these concentrations, suggesting that the mapped chromium distribution in that area is underestimated.

The measured and simulated mass recovery in the KX P&T system are in agreement, suggesting good representation of the chromium distribution in the fall 2014 mapped plume in the areas where KX extraction wells are located.

From a systematic perspective, the differences between the simulated and measured mass recovery could result from using estimated hydraulic and/or contaminant transport parameters in the transport model that do not accurately reflect actual conditions encountered at specific locations in the subsurface. The simulated mass recovery estimate, however, presents a useful tool for estimating the system performance over time and developing estimates of time to remediation.

3.2.9 Remedial Process Optimization Activities

Contractors have developed a pumping optimization model (based on the 100 Area groundwater model) that will be used by OU scientists, along with a detailed simulation display interface, to evaluate the relative performance of alternative well configurations. The OU scientists will evaluate pumping configurations throughout the year and provide adjustments to flow rates and recommendations for well realignment and/or the installation of new wells. Specific RPO activities performed at the 100-KR-4 OU during 2015 included the following:

- Designing and constructing two new monitoring wells at 105-KE Reactor with capability to function as high-performance extraction wells (i.e., using high-capacity well screens, and matching filter pack to screen and formation) if needed.

- Placing new and realigned extraction and injection wells (i.e., 199-K-208 and 199-K-124A) in service to enhance plume capture
- Identifying low-performing extraction wells for maintenance
- Initially using the pumping optimization model to evaluate expected extraction/injection well effects on plume capture

3.3 100-KR-4 Operable Unit Pump and Treat Systems Costs

This section summarizes the actual costs for the 100-KR-4 OU P&T systems for 2015. The primary categories of expenditures are described as follows:

- **Capital design:** Includes design activities to construct the P&T systems, including wells, and designs for major system upgrades and modifications.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the P&T system.
- **Project support:** Includes project coordination-related activities and technical consultation, as required, during the course of the facility design, construction, acceptance testing, and operation.
- **O&M:** Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes the costs associated with routine field screening and engineering support as required during the course of P&T operation and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis, as required in accordance with the 100-HR-3 and 100-KR-4 OU interim action work plan (DOE/RL-96-84).
- **Waste management:** Includes the cost for the management of spent resin at the 100-KR-4 OU in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Cost includes waste designation sampling and analysis, resin regeneration, and new resin purchase.

The costs include all activities associated with the interim remedial actions, including the construction of new wells and interim action performance monitoring. The 100-KR-4 OU costs for 2015 are associated with three P&T systems (KR4, KX, and KW). The total cost breakdown includes nonrecurring costs related to the installation of new wells and the P&T system modifications described in Section 3.2. The yearly cost breakdowns for each of the three 100-KR-4 OU P&T systems are shown in Tables 3-15 through 3-17, respectively. Costs are burdened and are based on actual operating costs incurred during 2015.

The costs for the three P&T systems for 2015 are lower due to completion of well realignments in 2014. Summaries of the costs for each P&T system are presented in the following subsections.

3.3.1 KR4 Pump and Treat System

The total cost for the KR4 P&T system during 2015 was $1.19 million, which consists of the sum of the categories shown in Table 3-15. The percentage that each category comprises of the total cost for the KR4 P&T system (Figure 3-25) is as follows, in decreasing order:

- O&M - 72.6 percent ($866,800)
- Treatment system capital construction - 10.3 percent ($123,000)

- Performance monitoring - 6.6 percent ($78,200)
- Project support - 6.3 percent ($75,400)
- Design - 3.9 percent ($47,100)
- Waste management – 0.3 percent ($3,400)
- No field studies were performed in 2015

Based on the total 2015 cost of $1,194,000, the yearly production rate of 655 million L (173 million gal), and 3.95 kg (8.7 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0018/L, or $302/g of Cr(VI) removed.

3.3.2 KX Pump and Treat System

The total cost for the KX P&T system for 2015 was $2.24 million (Table 3-16). The percentage that each category comprises of the total cost for the KX P&T system (Figure 3-26) is as follows, in decreasing order:

- O&M – 85.3 percent ($1,907,100)
- Treatment system capital construction - 5.5 percent ($122,900)
- Performance monitoring – 3.4 percent ($76,600)
- Project support – 3.4 percent ($75,400)
- Design – 2.3 percent ($51,500)
- Waste management – 0.1 percent ($3,300)
- No field studies were performed in 2015

Based on the total 2015 cost of $2,237,000, the yearly production rate of 1,588 million L (419 million gal), and 28.6 kg (62.9 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0014/L, or $78/g of Cr(VI) removed.

3.3.3 KW Pump and Treat System

The total cost for the KW P&T system during 2015 was $1.10 million, which consists of the sum of the categories shown in Table 3-17. The percentage that each category comprises of the total cost for the KW P&T system (Figure 3-27) is as follows, in decreasing order:

- O&M – 70.4 percent ($778.700)
- Treatment system capital construction - 11.1 percent ($123,000)
- Performance monitoring – 7.1 percent ($78,400)
- Project support – 6.8 percent ($75,400)
- Design – 4.3 percent ($47,100)
- Waste management – 0.3 percent ($3,500)
- No field studies were performed in 2015

Based on the total 2015 cost of $1,106,000, the yearly production rate of 651 million L (172 million gal), and 17.6 kg (38.7 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0017/L, or $63/g of Cr(VI) removed.

3.4 Conclusions

Remedial progress has been achieved for the plume areas associated with each of the three P&T systems currently active within the 100-KR-4 OU. The following conclusions for the OU are based on each of the RAOs:

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering the Columbia River.

  Results: Capture zone analysis indicates that operation of the KX, KW, and KR4 P&T systems has resulted in a capture efficiency of 74 to 94 percent over most of the 100-KR-4 OU Cr(VI) plumes above 10 µg/L.

  The combined hydraulic and water quality data evaluation indicates that the extent of hydraulic containment developed by the KX, KW, and KR4 P&T systems during 2015 improved compared to 2014. This improvement is consistent with expectations from well locations and planned extraction rates. Calculations indicate that the river protection objective is being achieved along the majority of the 100-KR-4 OU shoreline. The performance of remedial action systems currently in place in the 100-KR-4 OU confirms that DOE has taken necessary measures to control the discharge of Cr(VI) into the Columbia River. The one location along the 100-KR-4 OU river shore that was identified as "not protected" during 2015 is associated with a zone of aquifer stagnation generated due to increased pumping at five extraction wells; alternatively, a secondary source may be present in the area. Further evaluation of this condition is needed and may require adjustments to pumping rates.

  Based on the aquifer tube data for 2015, the general extent and concentration of Cr(VI) discharged to the Columbia River within the 100-KR-4 OU has decreased in response to P&T activities. The exception is the localized area at the downgradient edge of the plume at the head end of the 116-K-2 Trench.

  The 100-KR-4 OU P&T systems have removed substantial amounts of Cr(VI) from the unconfined aquifer. In total, the systems have removed an estimated 836 kg (1,843 lb) of Cr(VI) from the shallow unconfined aquifer.

  - The KR4 P&T system has removed a substantial mass of Cr(VI) from the plume zones located along the 116-K-2 Trench. Between September 1997 and December 31, 2015, the KR4 P&T system extracted and treated approximately 8.0 billion L (2.1 billion gal) of groundwater, resulting in the removal of 375 kg (827 lb) of Cr(VI) from the aquifer. As a result of remediation activities, Cr(VI) concentrations have been reduced in most wells.

  - The KR4 P&T system has attained the RAO for river protection along the central portion of the 116-K-2 Trench area.

  - The KW P&T system started operating in January 2007. As of December 31, 2015, the system had extracted approximately 3.6 billion L (951 million gal) of groundwater and removed an estimated 238 kg (525 lb) of Cr(VI). By the end of 2015, all wells associated with the KW P&T system exhibited Cr(VI) concentration below 20 µg/L.

  - The KX P&T system was designed to treat the K North Cr(VI) plume, located between the northern end of the 116-K-2 Trench and the N Reactor fence line. Since system startup in February 2009, more than 7.4 billion L (2.0 billion gal) of water have been treated, and approximately 223 kg (492 lb) of Cr(VI) have been removed.

  The observed concentrations of Cr(VI) in groundwater at all three of the 100-KR-4 OU P&T systems are declining as remediation progresses.

- **RAO #2:** Protect human health by preventing exposure to contaminants in groundwater.

  Results: The interim remedial action ROD (EPA/ROD/R10-96/134) establishes a variety of ICs that must be implemented and maintained throughout the interim action period. These provisions include the following:

  – Access control and visitor escorting requirements
  – Signage providing visual identification and warning of hazardous or sensitive areas
  – Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  – Regulatory agency notification of any trespassing incidents

  The effectiveness of ICs is presented in DOE/RL-2004-56. ICs remain in operation in 100-KR-4 OU.

- **RAO #3:** Provide information that will lead to a final remedy.

  Results: Additional information on the groundwater contamination at the 100-KR-4 OU continues to be gathered. Ongoing groundwater monitoring activities provide information on the changes in contaminant concentrations, as well as the spatial distribution of the groundwater plumes. Assessment of information collected during source remediation actions provides details regarding the sources of groundwater contamination and the potential for continuing contributions from secondary sources within the vadose zone for hexavalent chromium as well as other contaminants of concern in this OU.

  An evaluation of information from multiple activities indicates that while the interim groundwater remedial actions at the 100-K Area have been successful to reduce Cr(VI) concentrations and reduce plume sizes across the OU, residual secondary sources likely remain at multiple locations. A final remedy will need to address ongoing contributions from vadose zone sources, as well as high contaminant concentrations in groundwater at or near source release areas. During 2015, two characterization boreholes were drilled near KE Reactor, and soil and groundwater samples collected during drilling confirmed the presence of vadose zone contamination at these two locations, as well as associated groundwater contamination. This information will be incorporated into the final 100-K Area RI/FS report.

3.5 Recommendations

Recommendations for the 100-KR-4 OU are as follows:

- Continue RPO activities for the 100-KR-4 OU P&T systems to:
  – Evaluate the well network for improved efficiencies to maximize the use of treatment system capacity, particularly during periods of low river stage when treatment capacity usage has historically decreased.

  – Evaluate and identify adjustments to pumping rates, locations for new well installation, and/or well realignments to meet the primary objectives (i.e., control hydraulic gradients, protect the Columbia River, remove contaminant mass, and restore the aquifer).

- Develop and prioritize well additions and/or realignments based on the RPO evaluations to include future planning for the P&T systems.

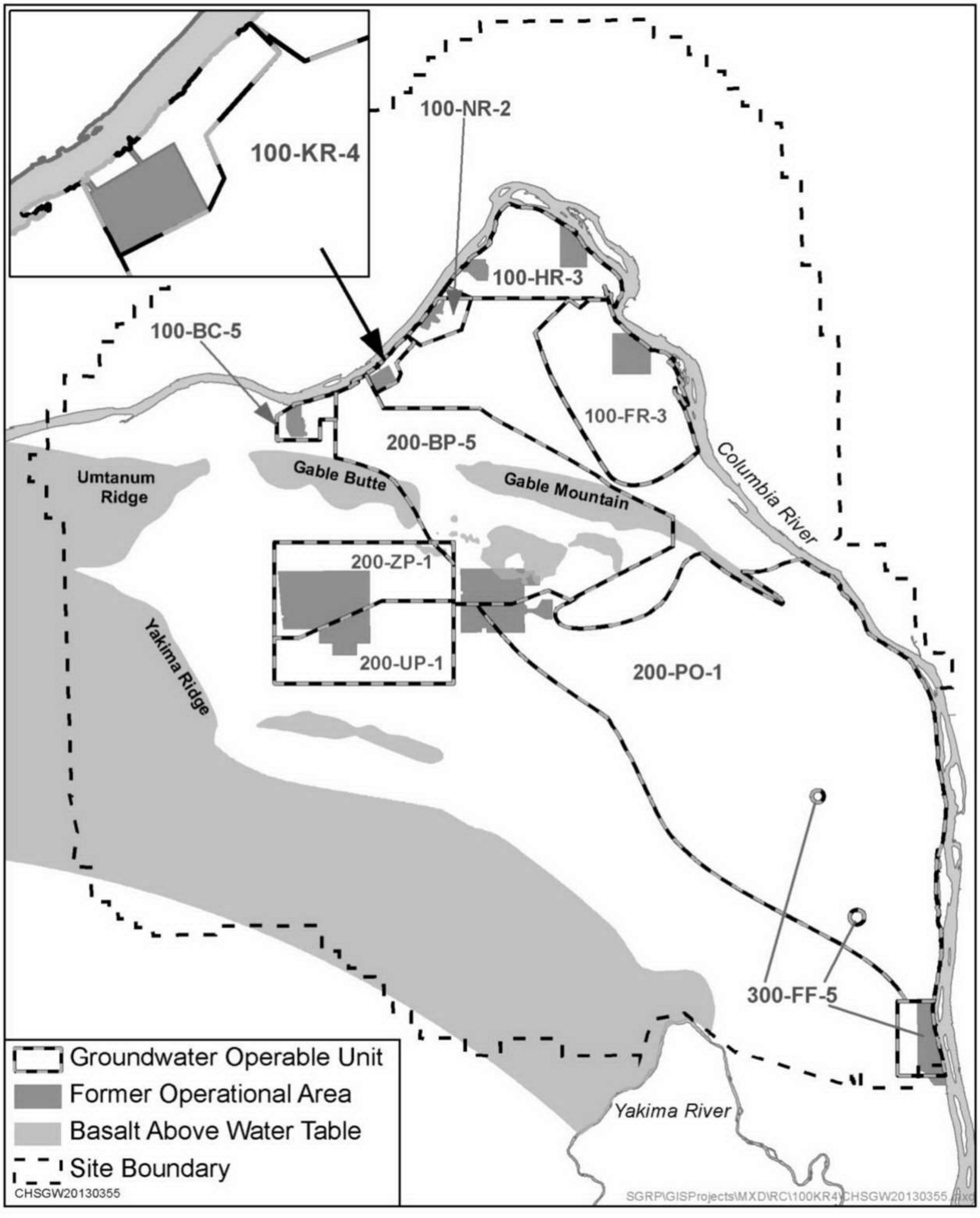


Figure 3-1. Location of the Hanford Site and the 100-KR-4 OU

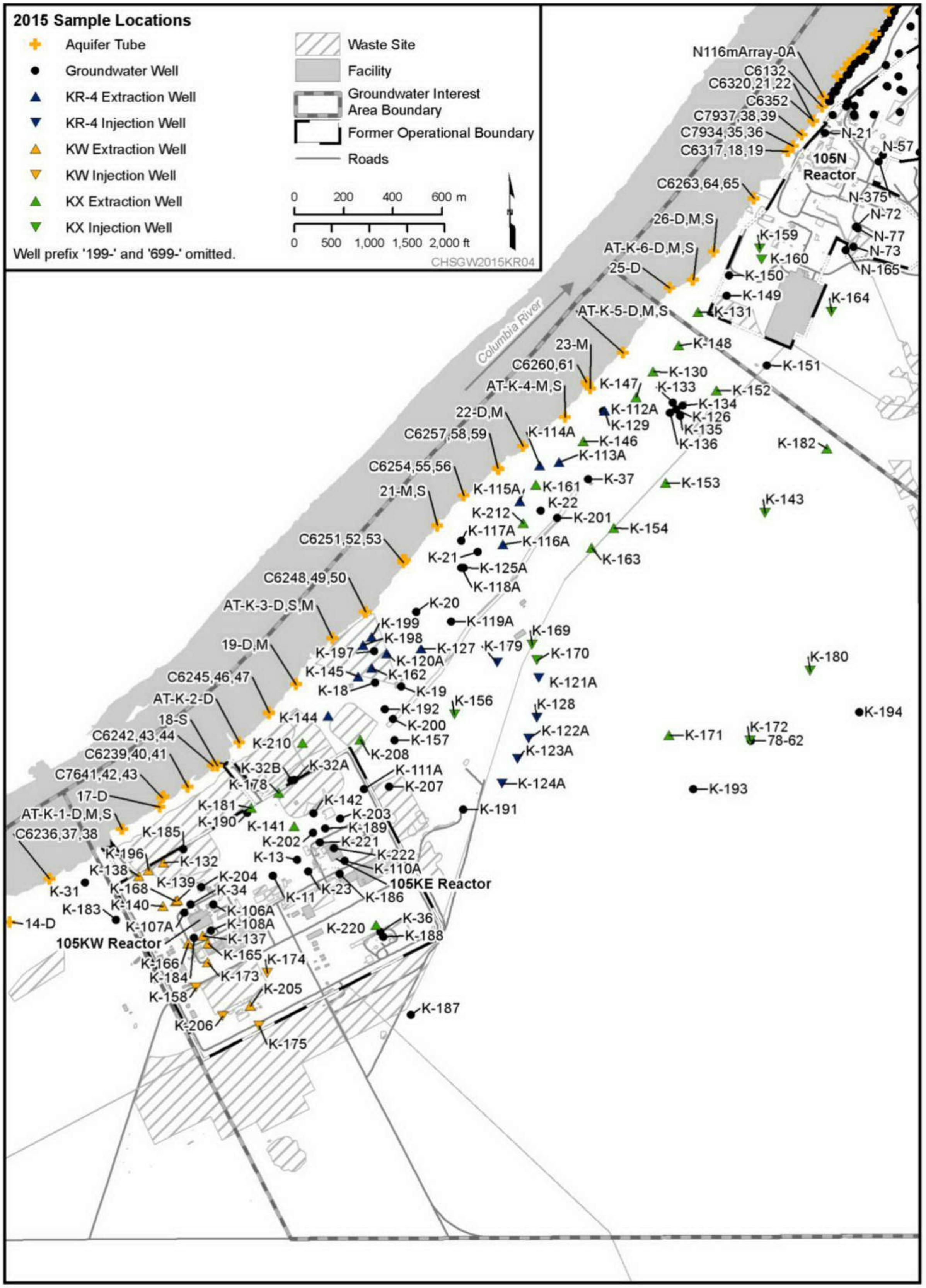


Figure 3-2. 100-KR-4 OU Remedial System Wells, Monitoring Wells, and Aquifer Sampling Tubes

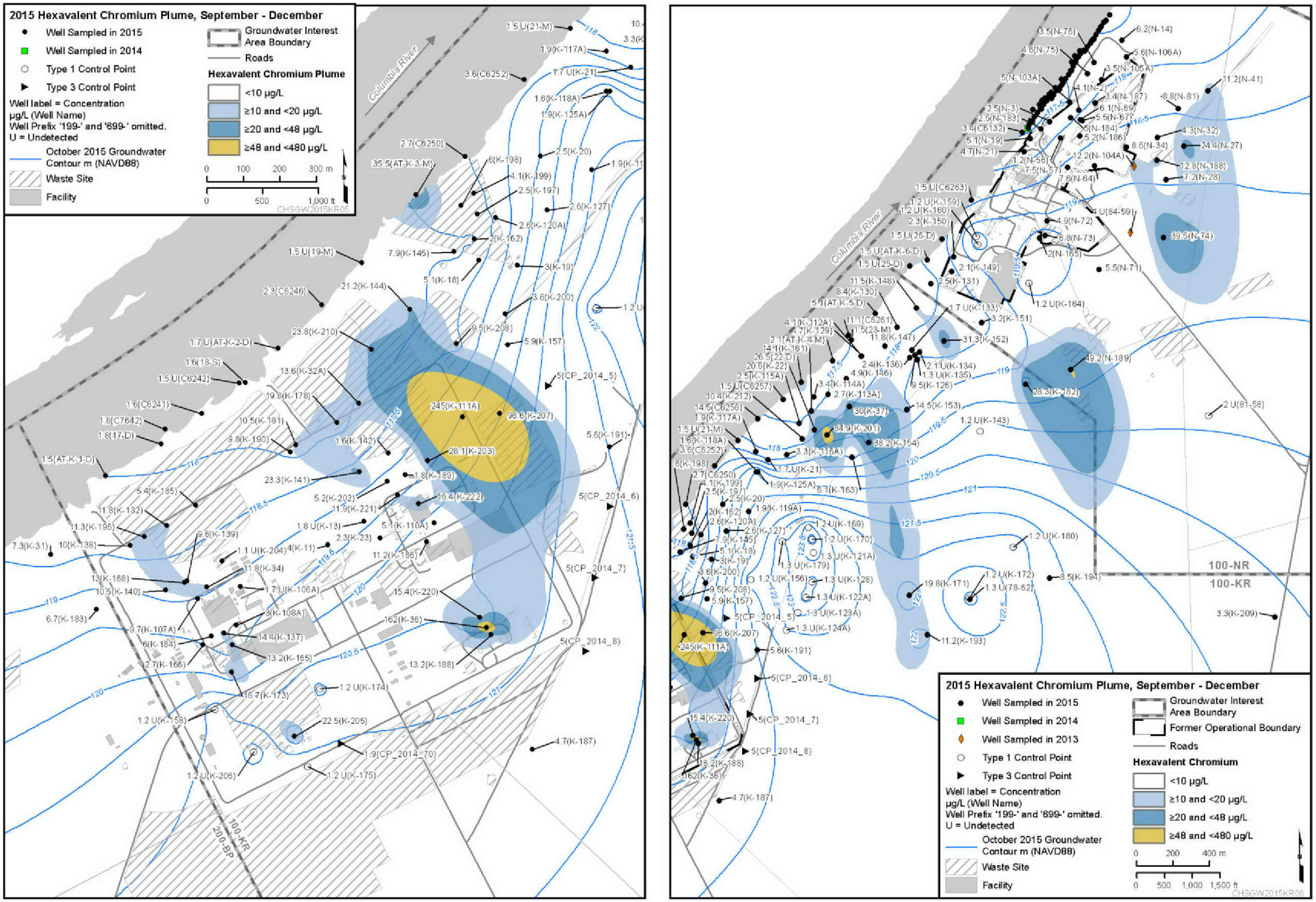


Figure 3-3. Cr(VI) Plume Distribution in Groundwater at the 100-KR-4 OU (Low River Stage, 2015)

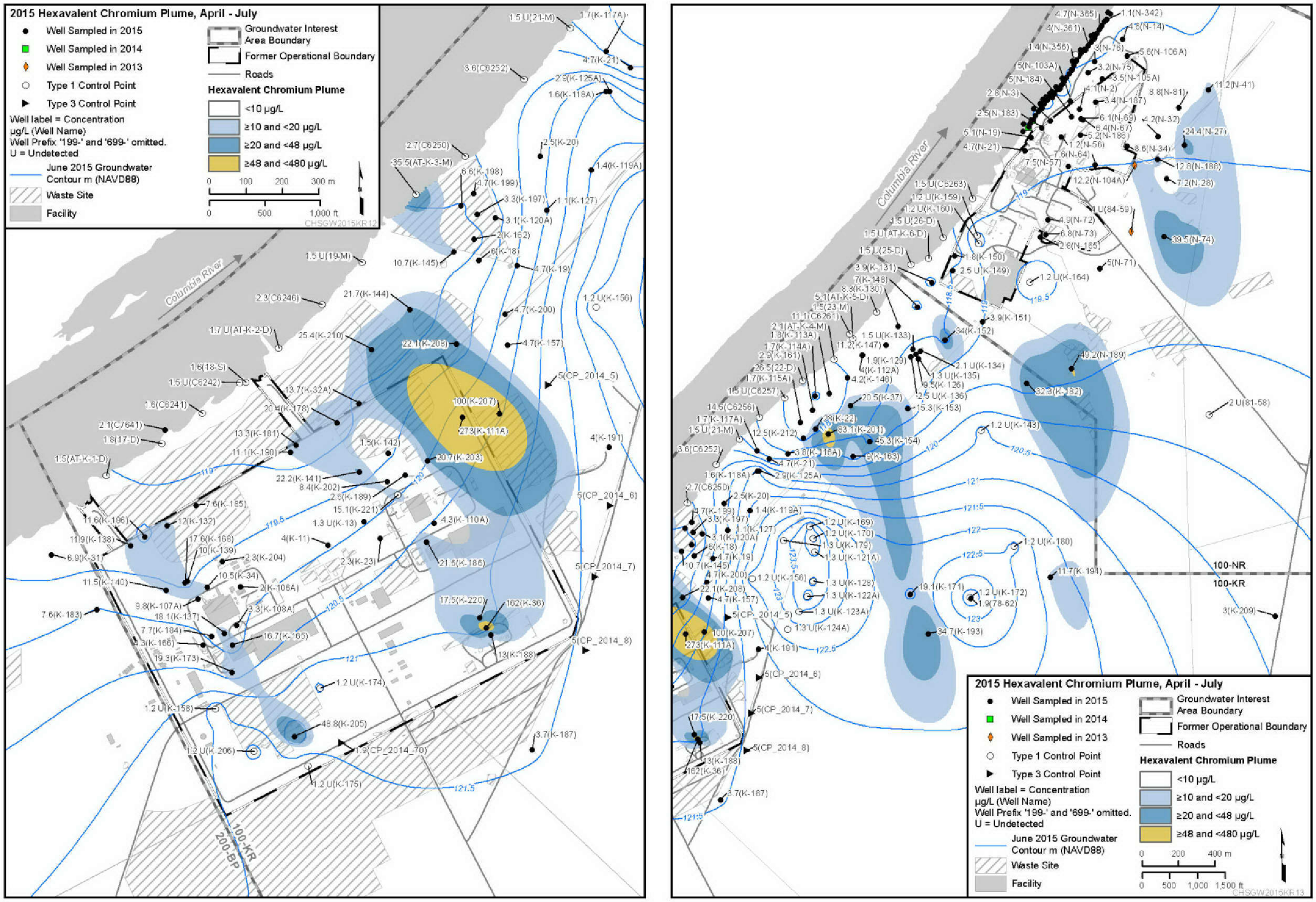


Figure 3-4. Cr(VI) Plume Distribution in Groundwater at the 100-KR-4 OU (High River Stage, 2015)

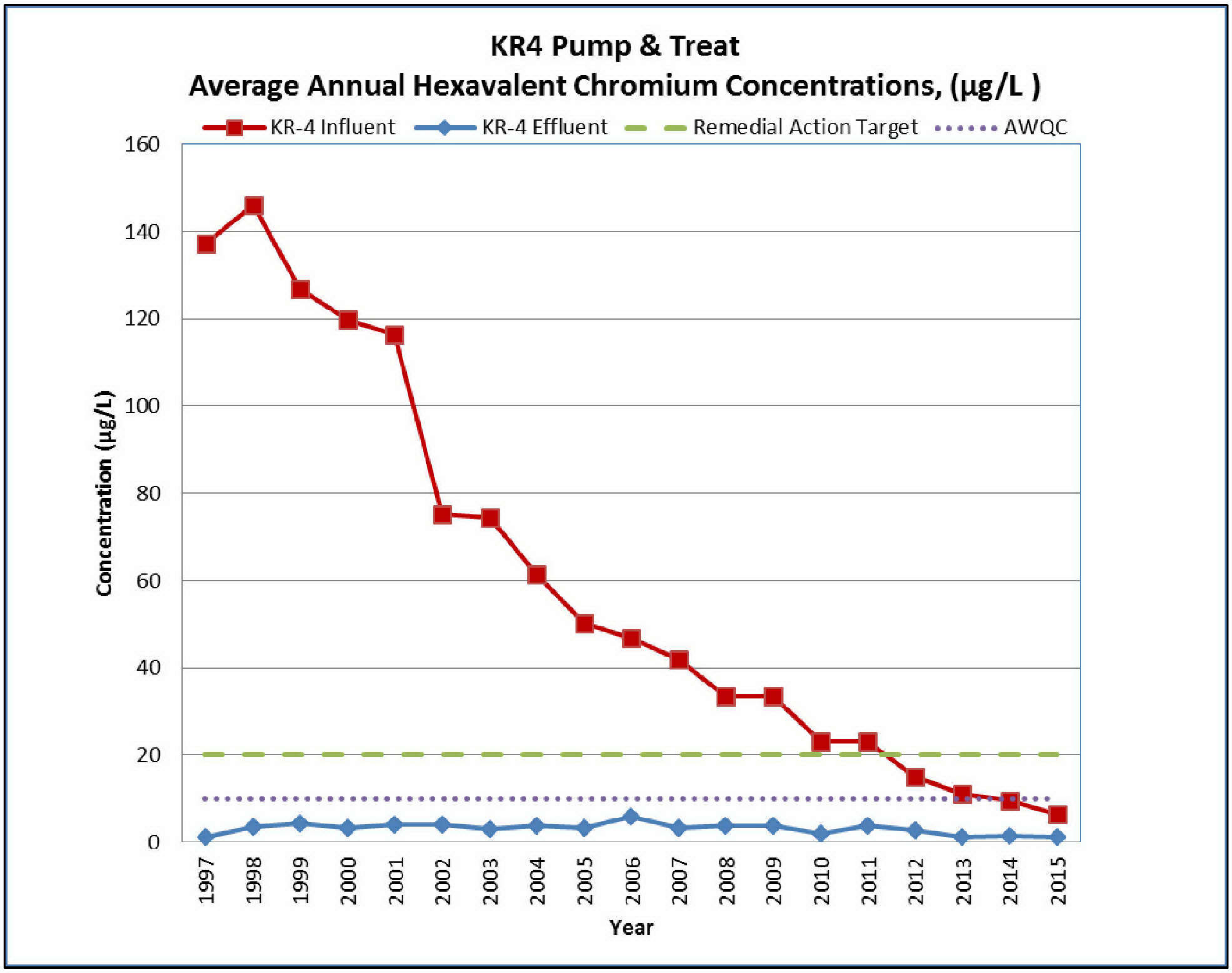


Figure 3-5. KR4 P&T System Annual Average Influent and Effluent Concentrations

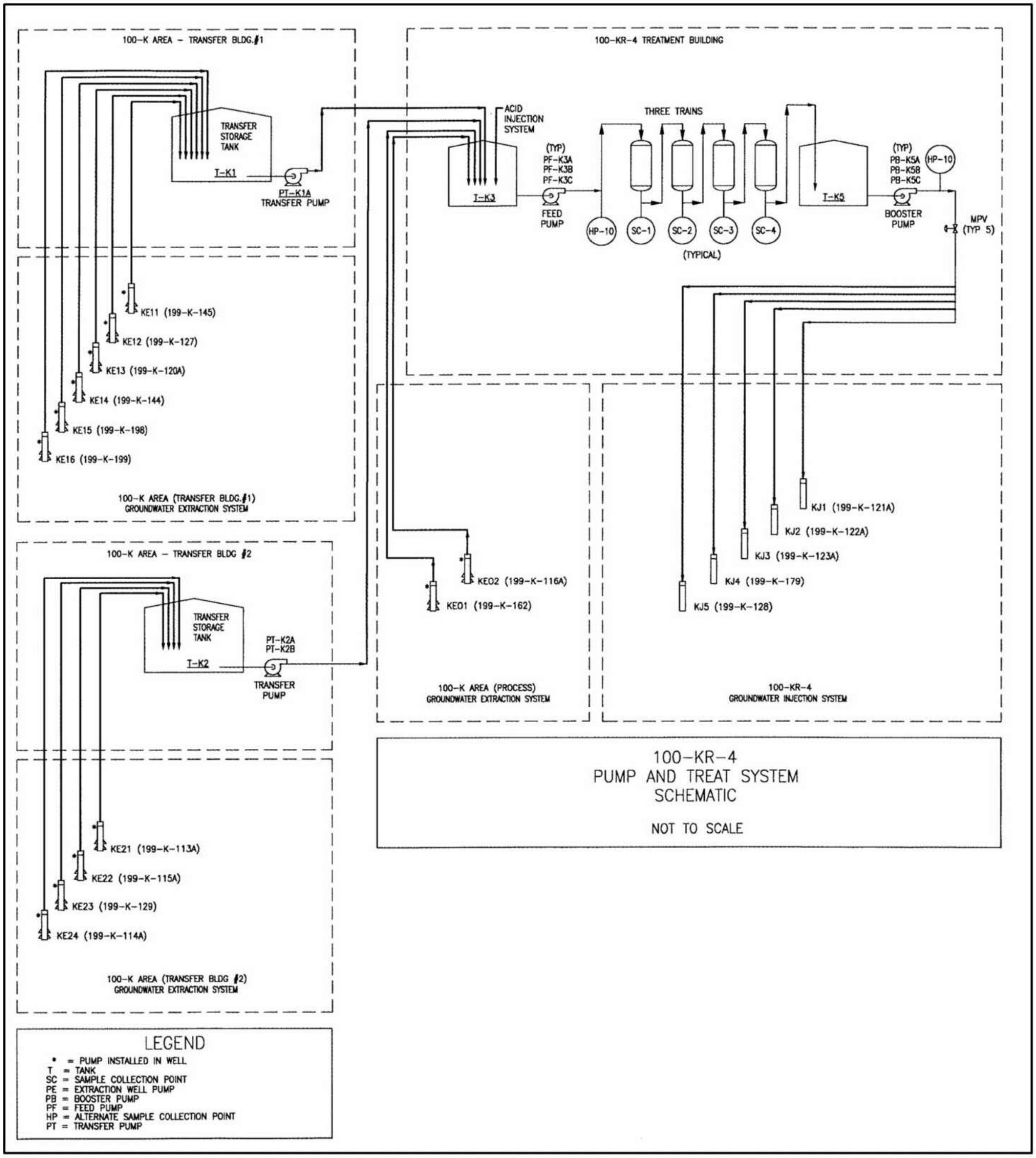


Figure 3-6. KR4 P&T System Schematic

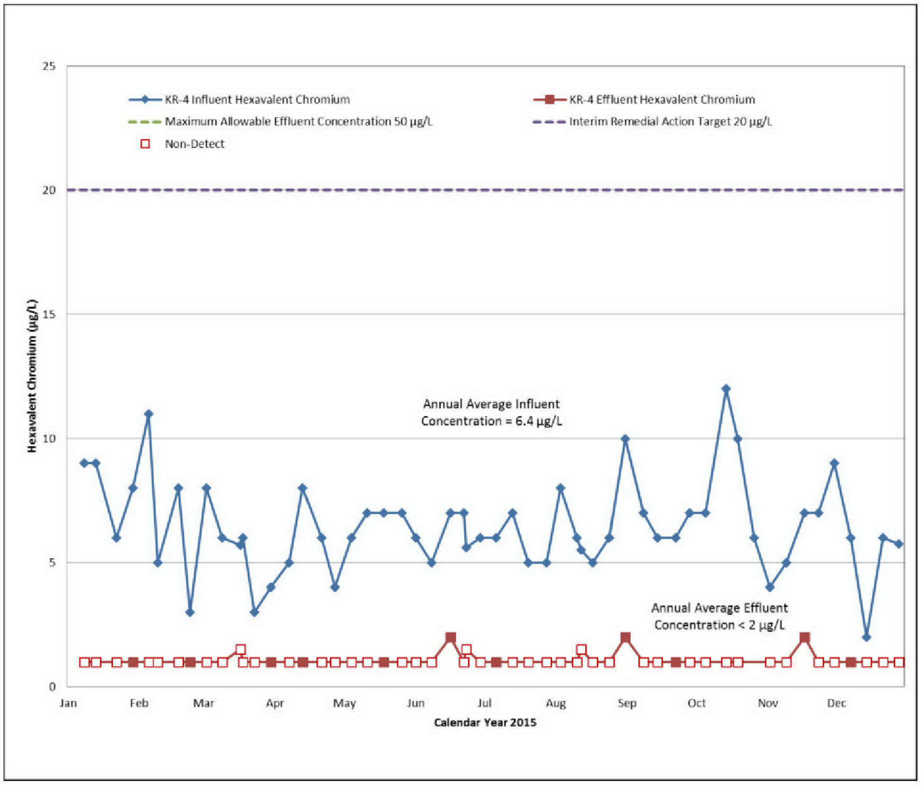


Figure 3-7. KR4 P&T System Trends of Influent and Effluent Cr(VI) Concentrations, 2015

Figure 3-8. Monthly Online Availability for the KR4 P&T System, 2015

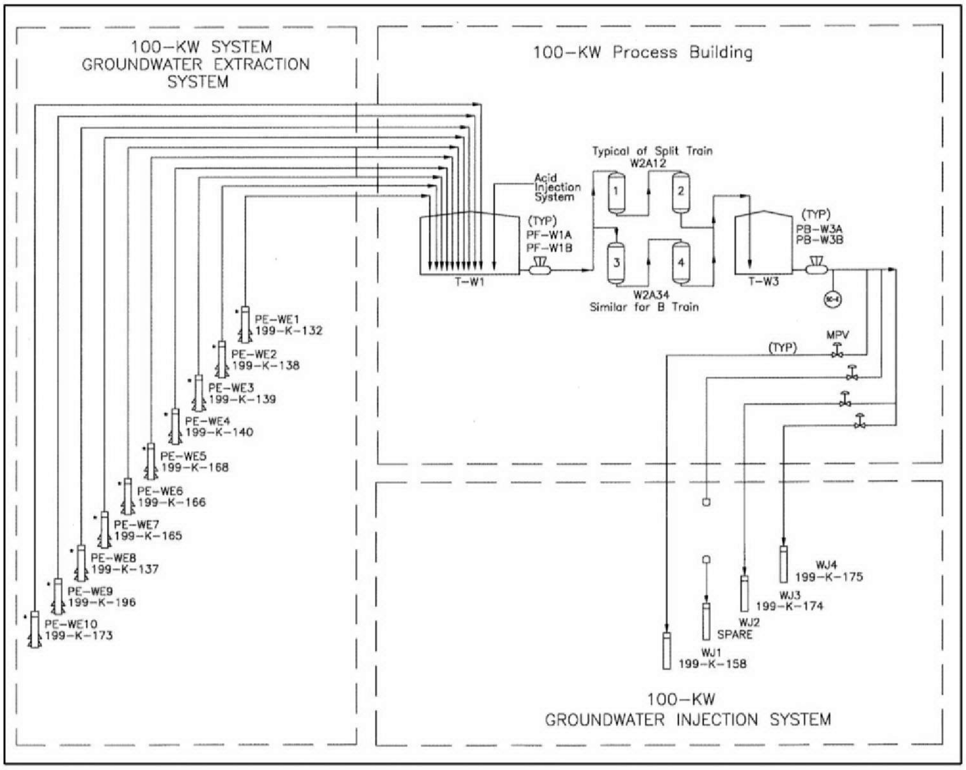


Figure 3-9. KW Reactor Area P&T System Schematic

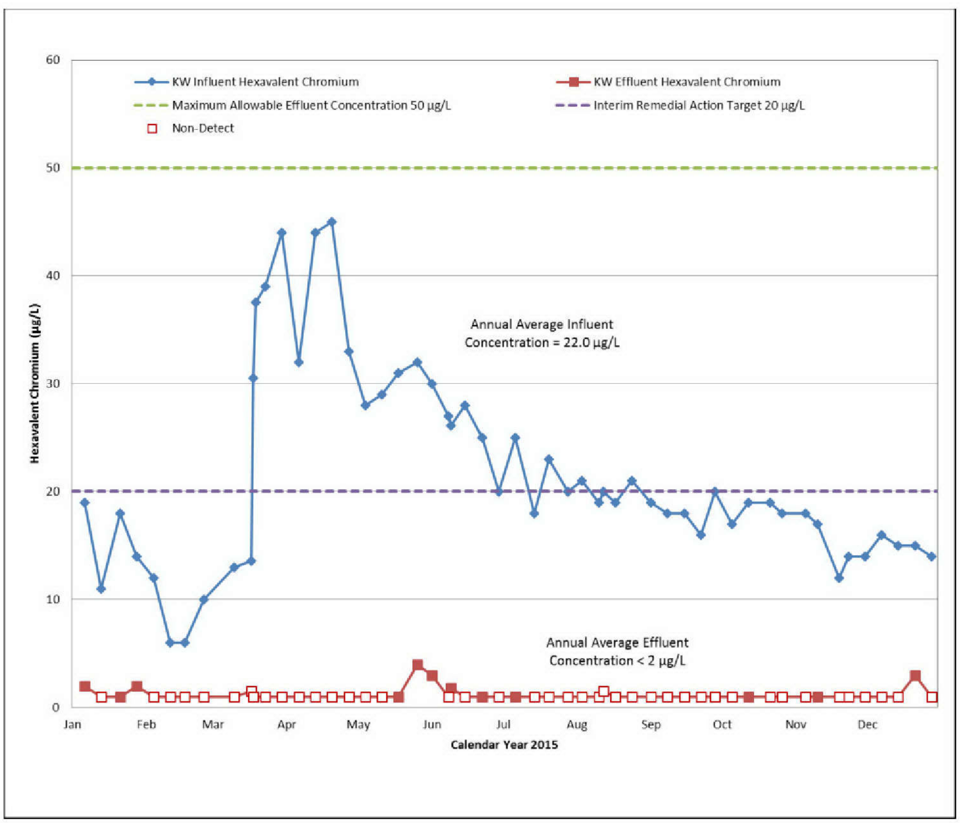


Figure 3-10. KW P&T Trends for Influent and Effluent Cr(VI) Concentrations, 2015

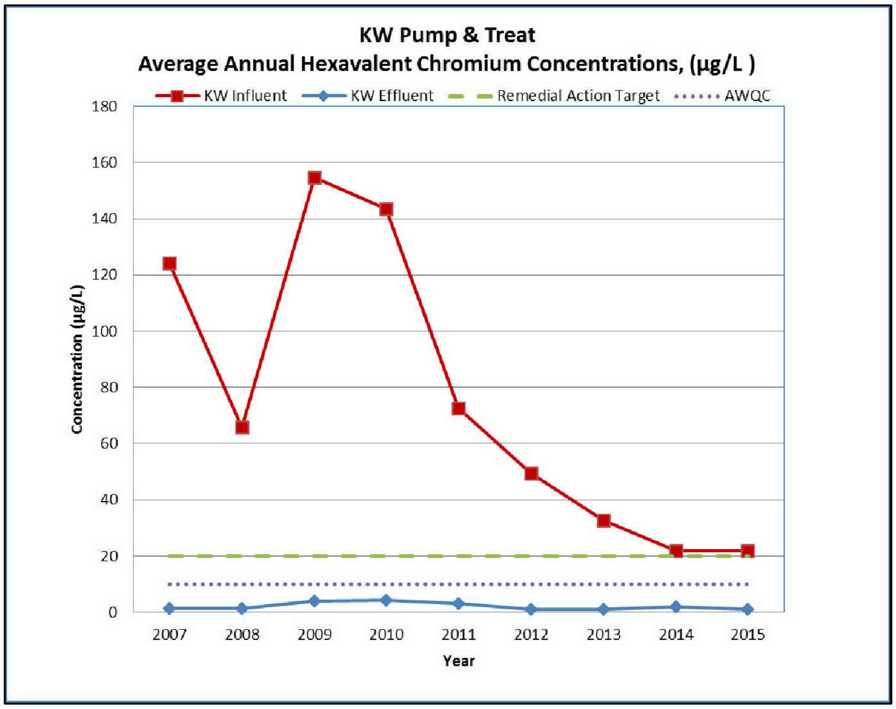


Figure 3-11. KW P&T System Annual Average Influent and Effluent Concentrations

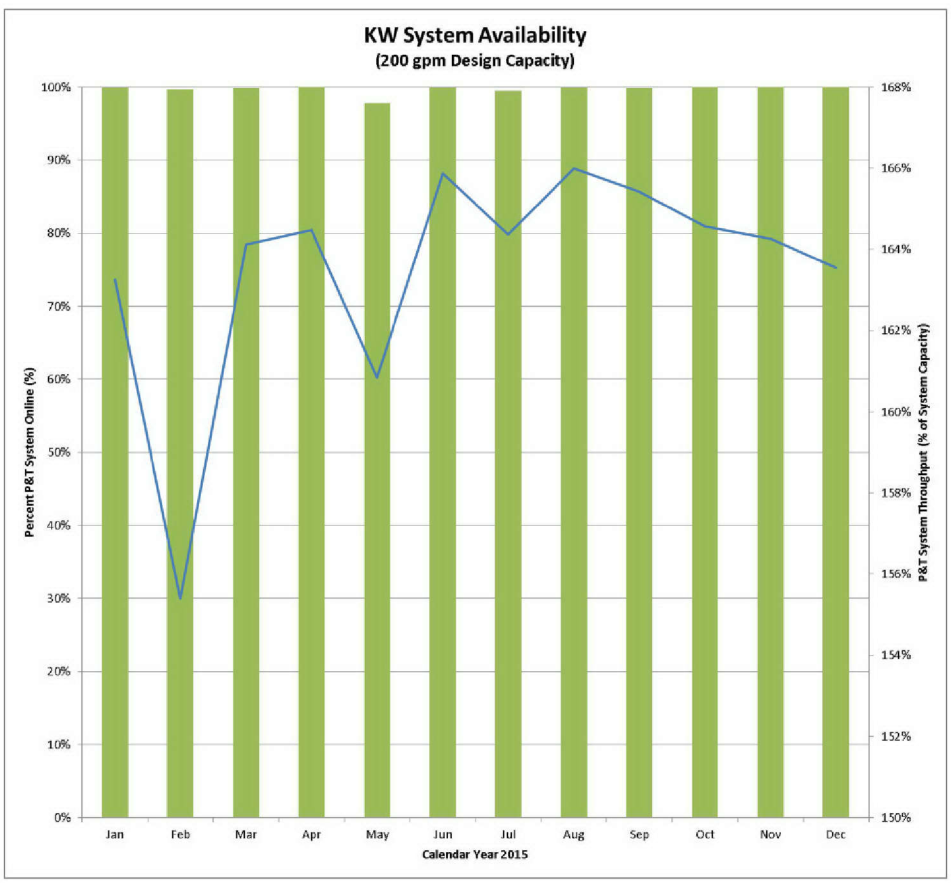


Figure 3-12. Monthly Online Availability for the KW P&T System, 2015

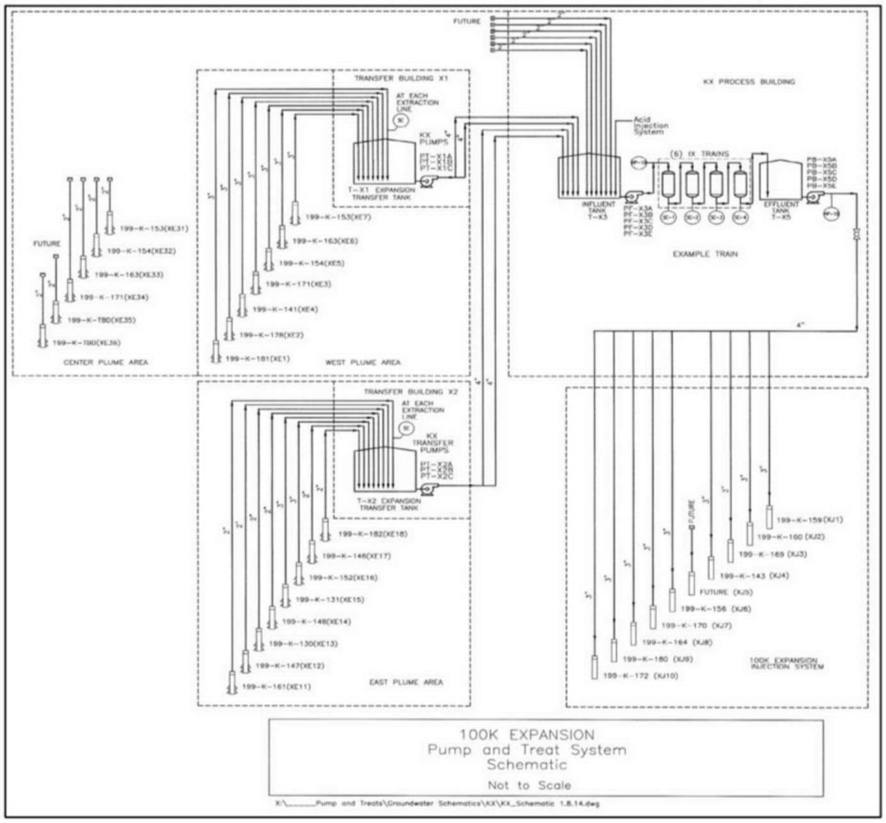


Figure 3-13. KX P&T System Schematic

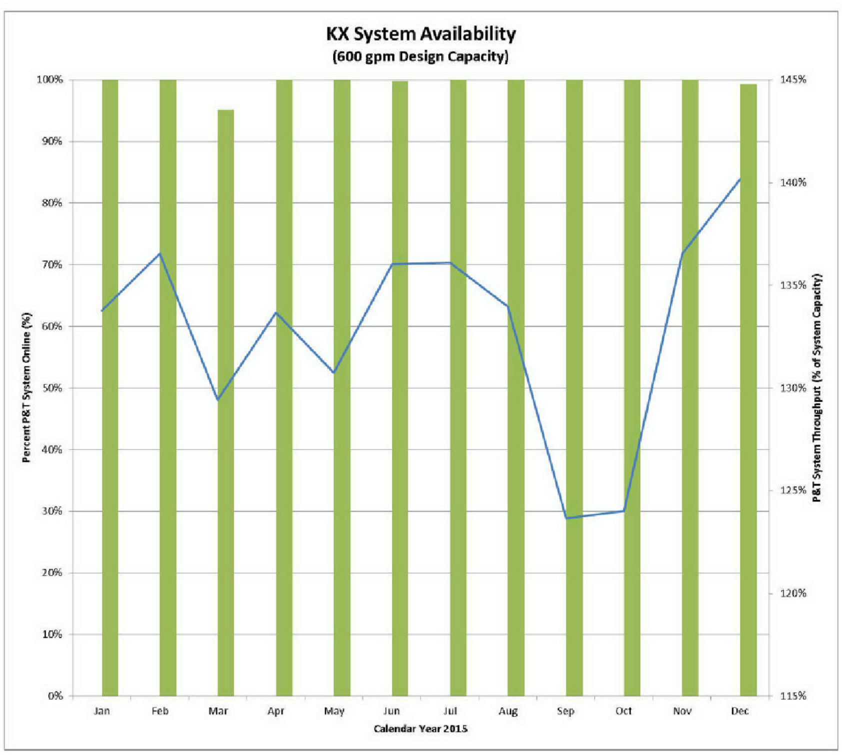
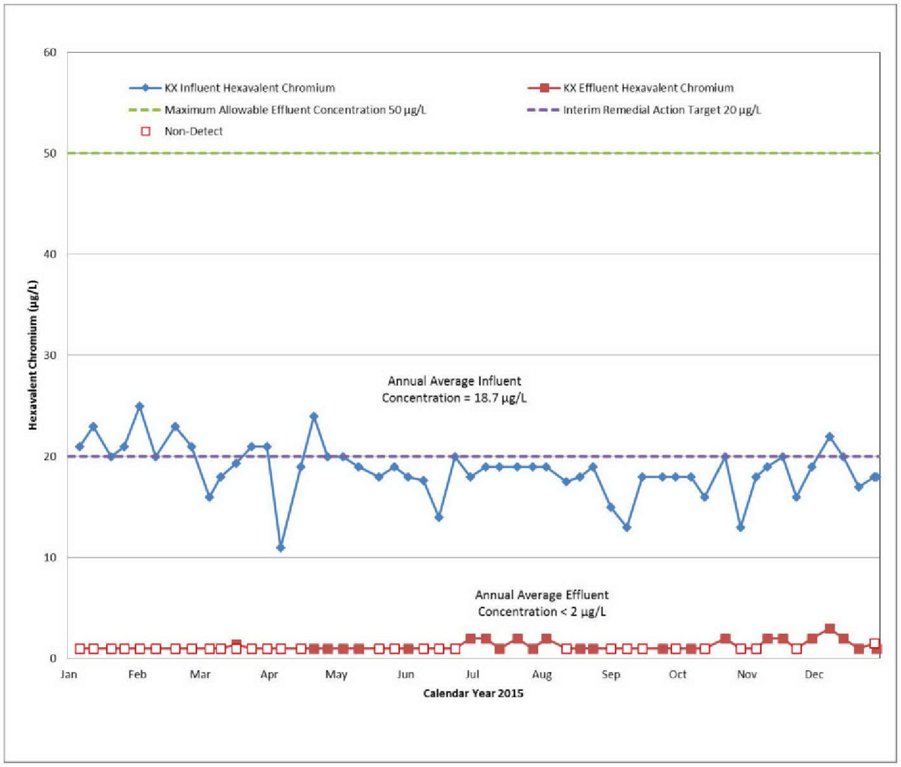


Figure 3-14. Monthly KX P&T System Availability, 2015



Note: These trends reflect a combination of laboratory and in-plant measurements.

Figure 3-15. KX P&T System Trends of Influent and Effluent Cr(VI) Concentrations, 2015

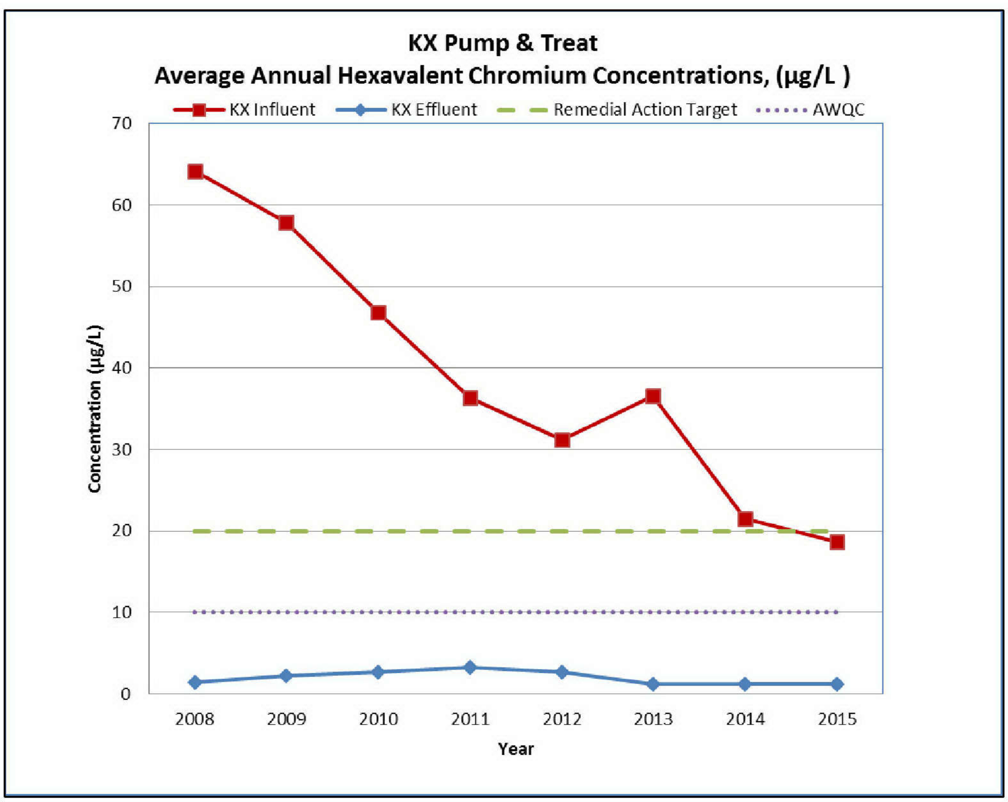


Figure 3-16. KX P&T System Annual Average Influent and Effluent Concentrations

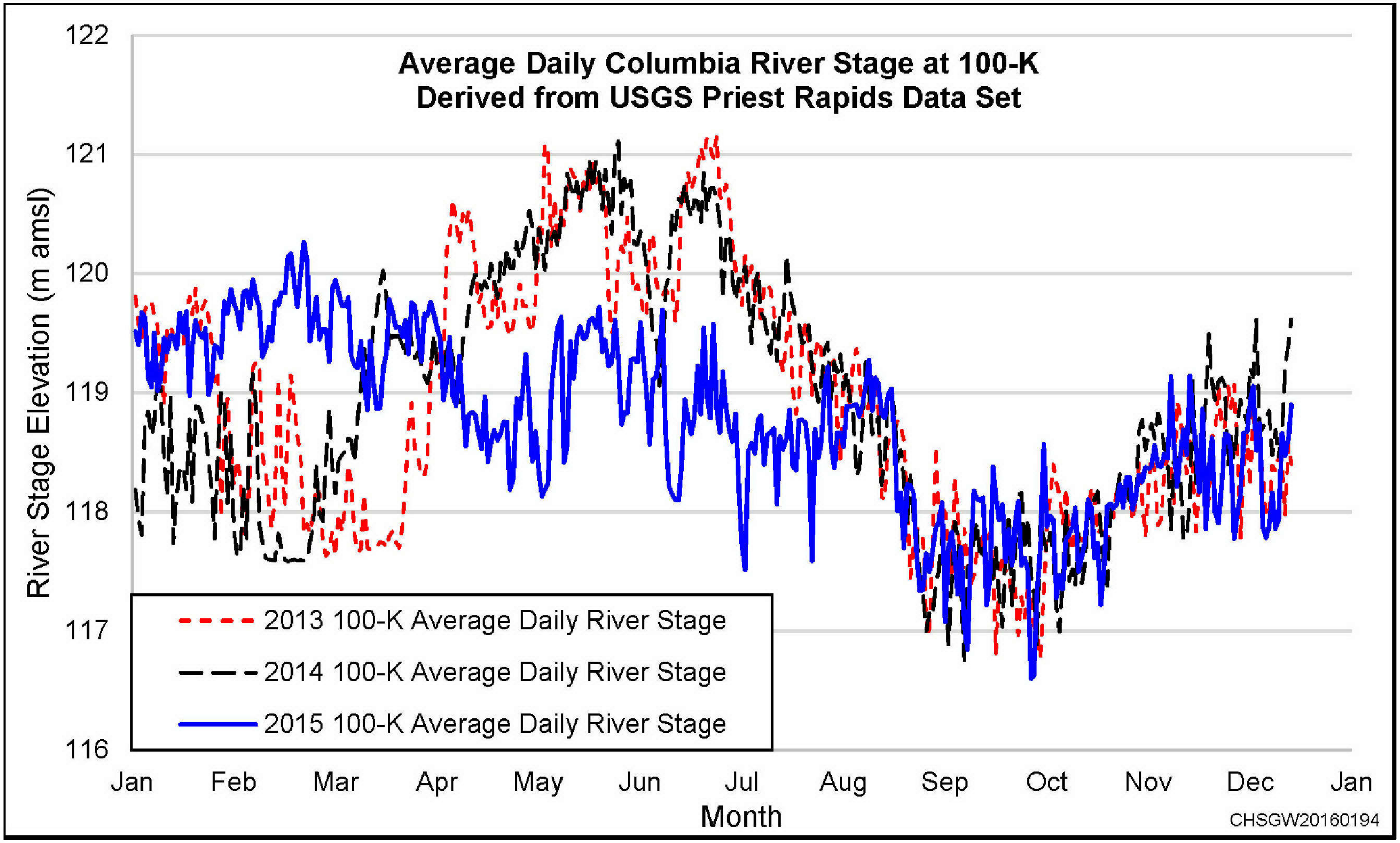


Figure 3-17. Columbia River-Stage Elevation at the 100-K Area, 2015 (96-Point Moving Average Represents Daily Average River Stage)

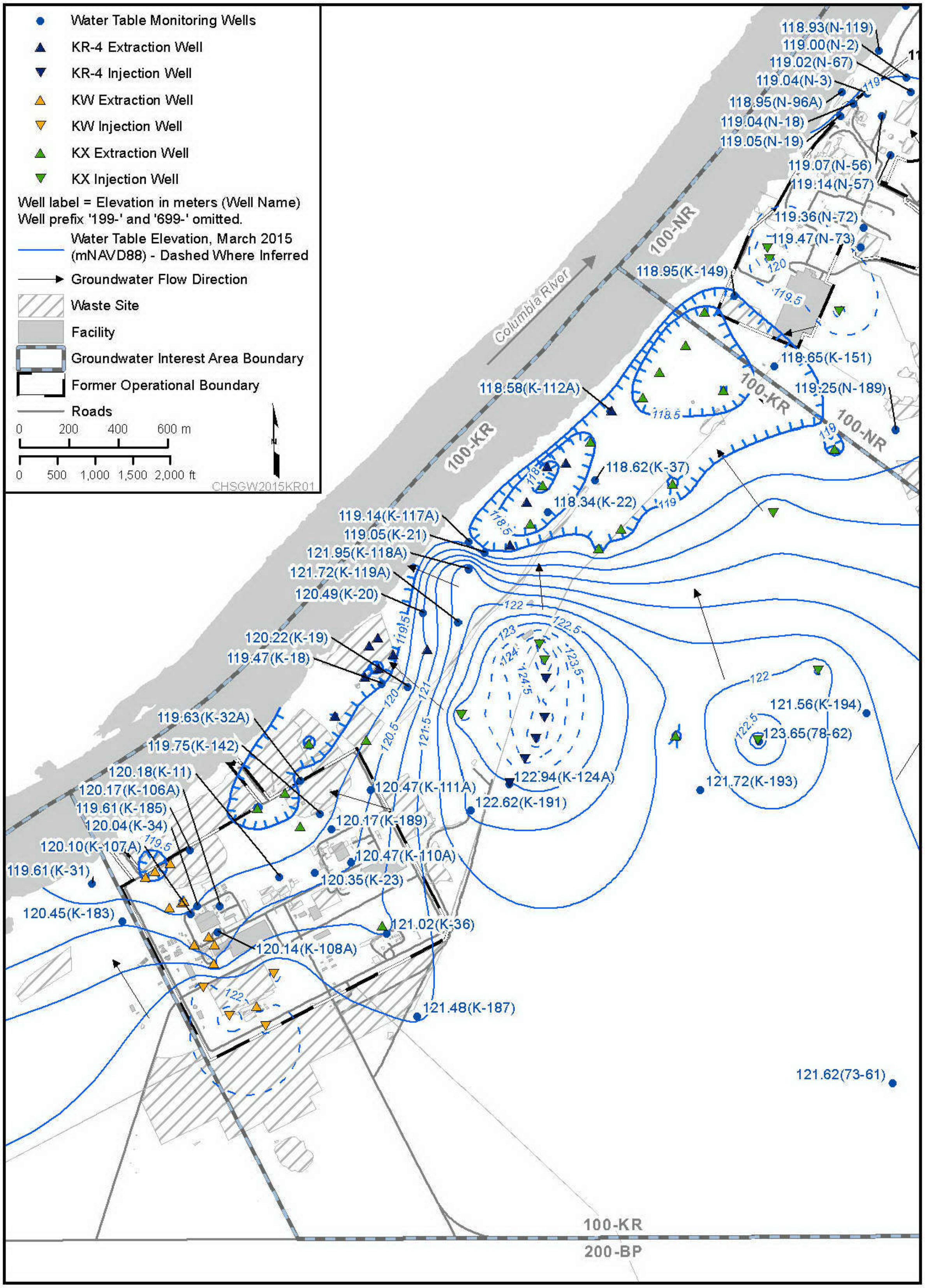


Figure 3-18. Groundwater Elevation Contour Map, March 2015

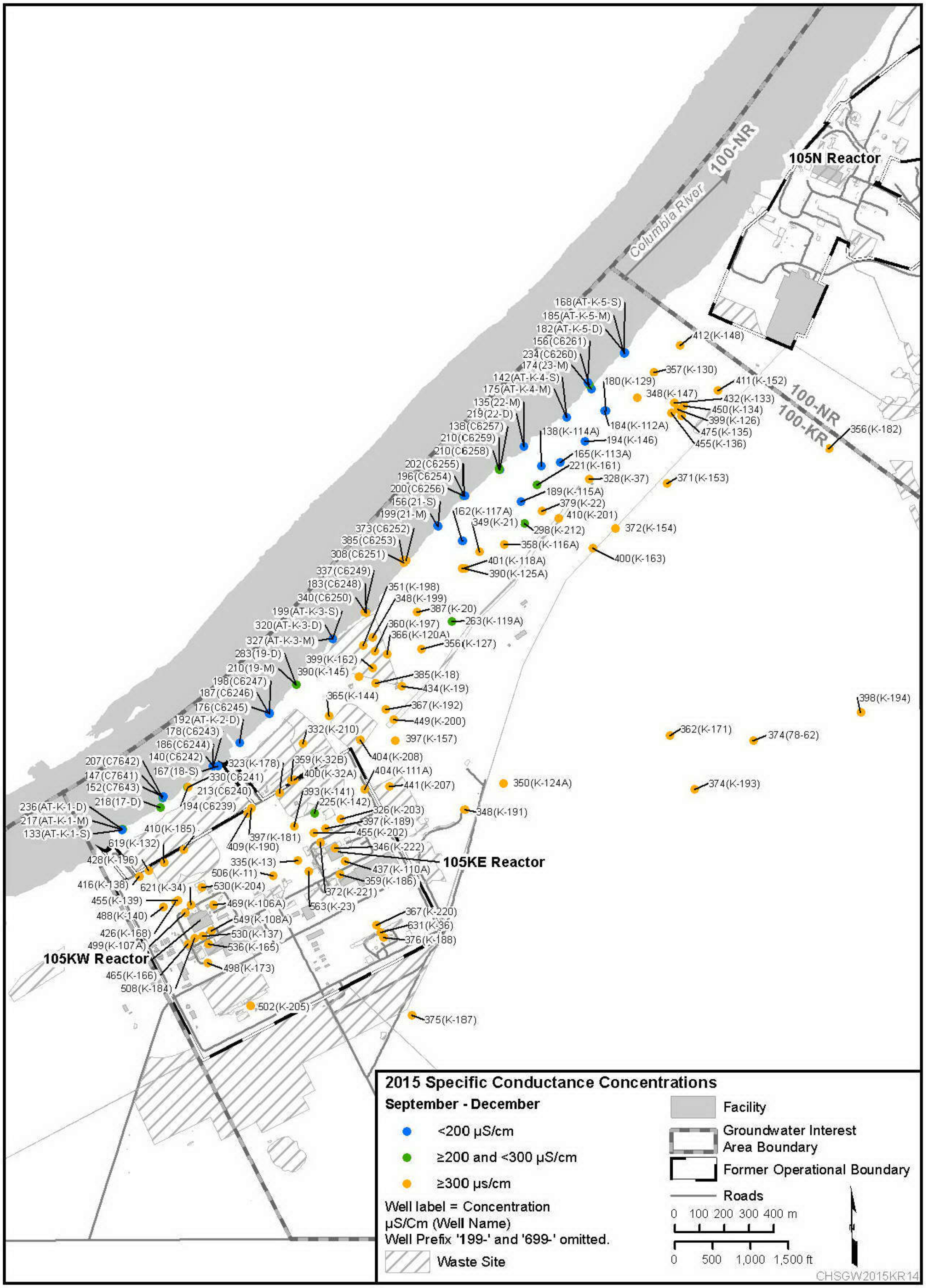


Figure 3-19. Plot of Groundwater Specific Conductance Relative to the Columbia River, 2015

This page intentionally left blank.

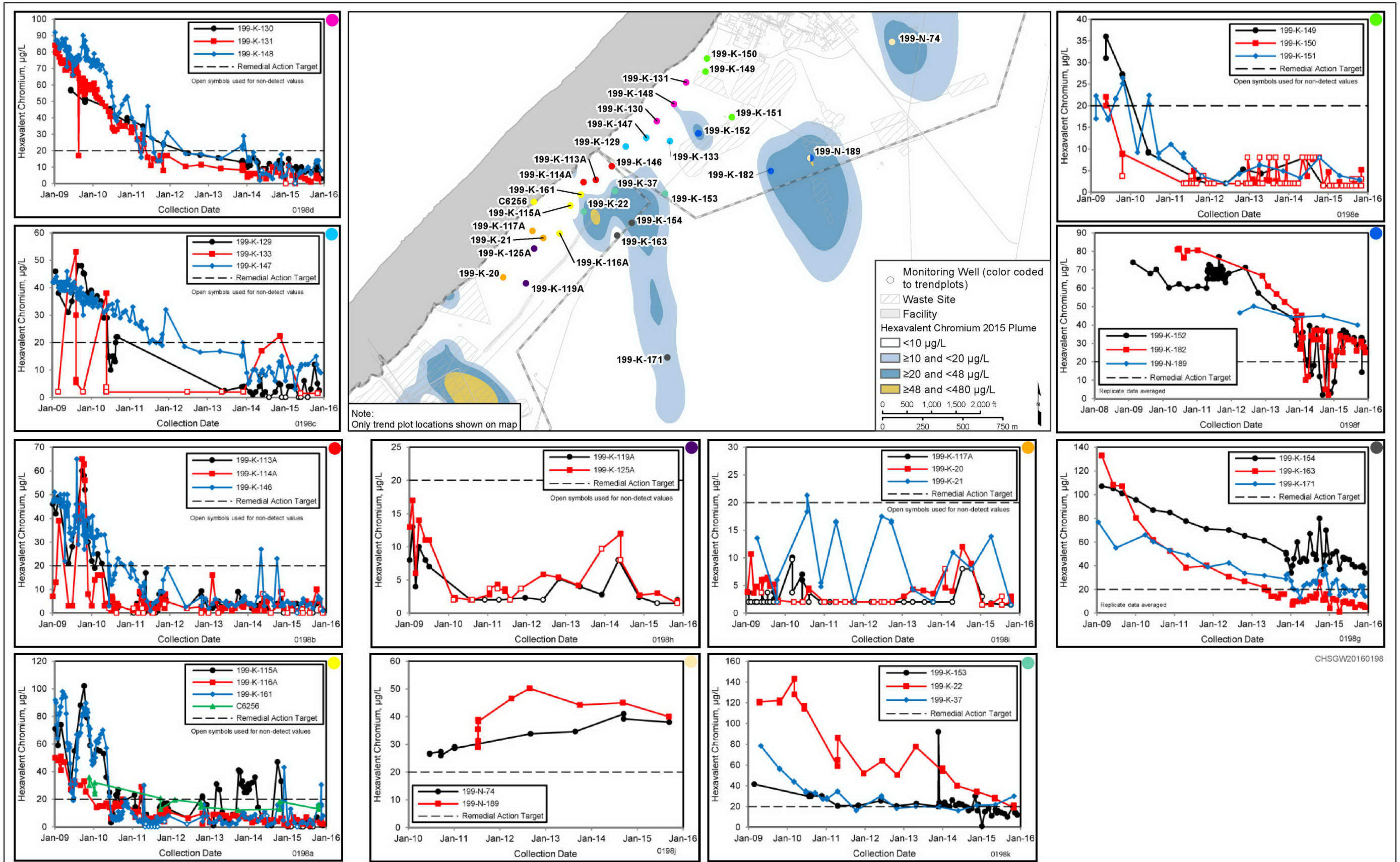


Figure 3-20. 2015 Cr(VI) Groundwater Concentration Time-Series Plots for Selected Wells near the 116-K-2 Trench Source Area

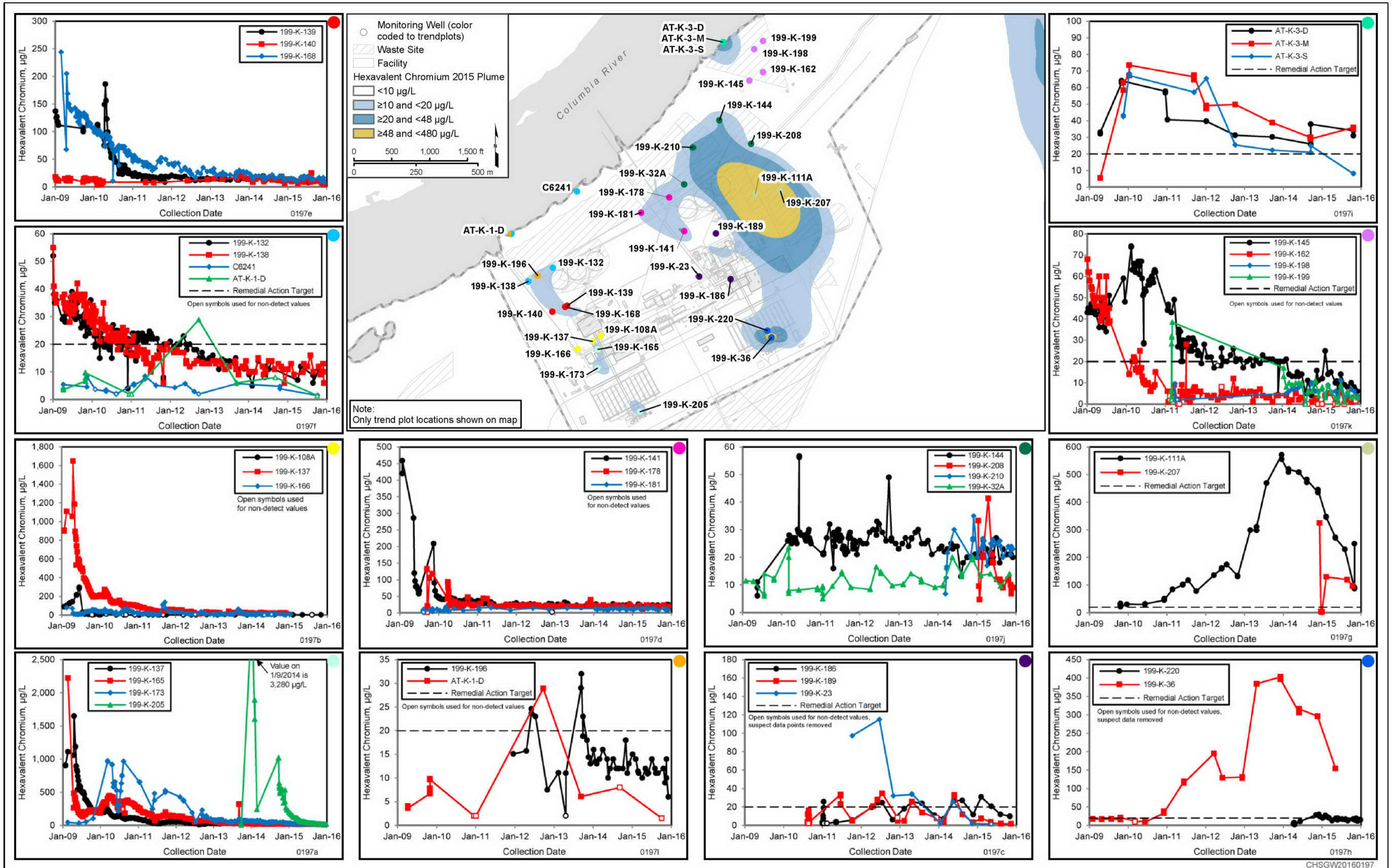


Figure 3-21. 2015 Cr(VI) Groundwater Concentration Time-Series Plots for Selected Wells near the KE and KW Reactors

Figure 3-22(a). 2015 100-K Area Interpolated CFM and High River-Stage Chromium Contamination

Figure 3-22(b). 2015 100-K Area Simulated CFM and High River-Stage Chromium Contamination

Figure 3-22(c). 2015 100-K Area Interpolated CFM and Low River-Stage Chromium Contamination

Figure 3-22(d). 2015 100-K Area Simulated CFM and Low River-Stage Chromium Contamination

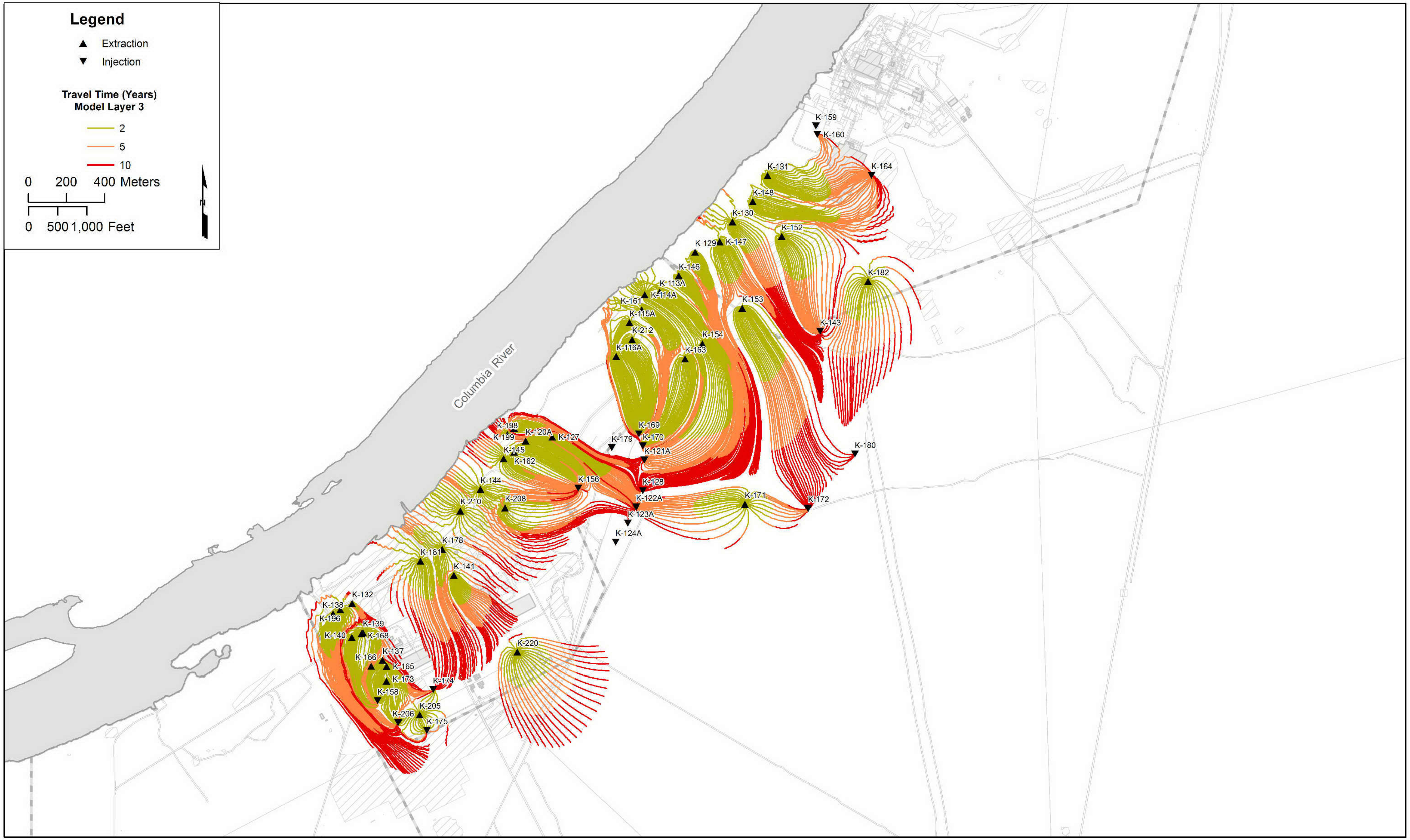


Figure 3-22(e). 100-K Area Groundwater Flow Lines of Capture Zone for 2015 Flow Field

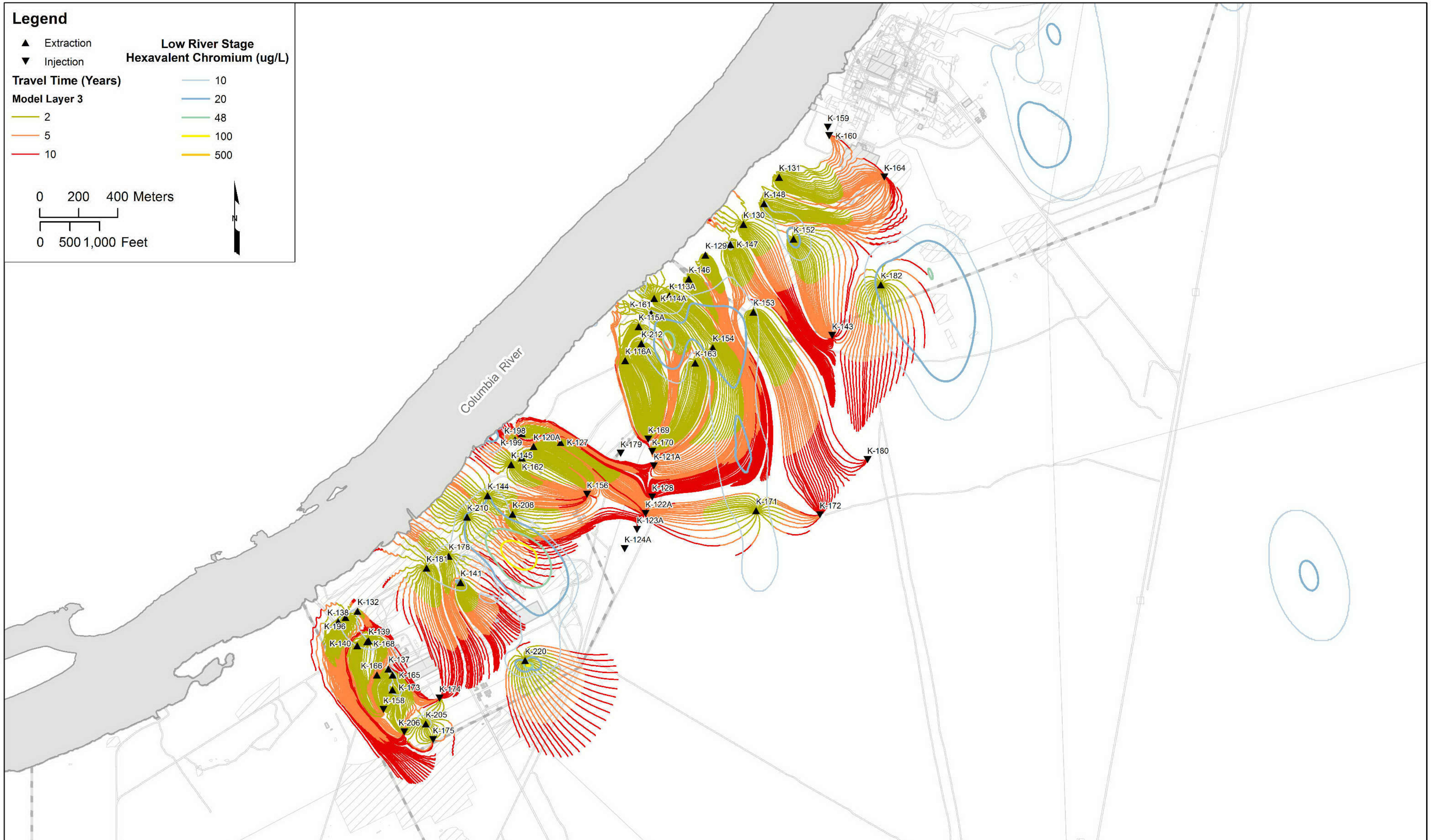
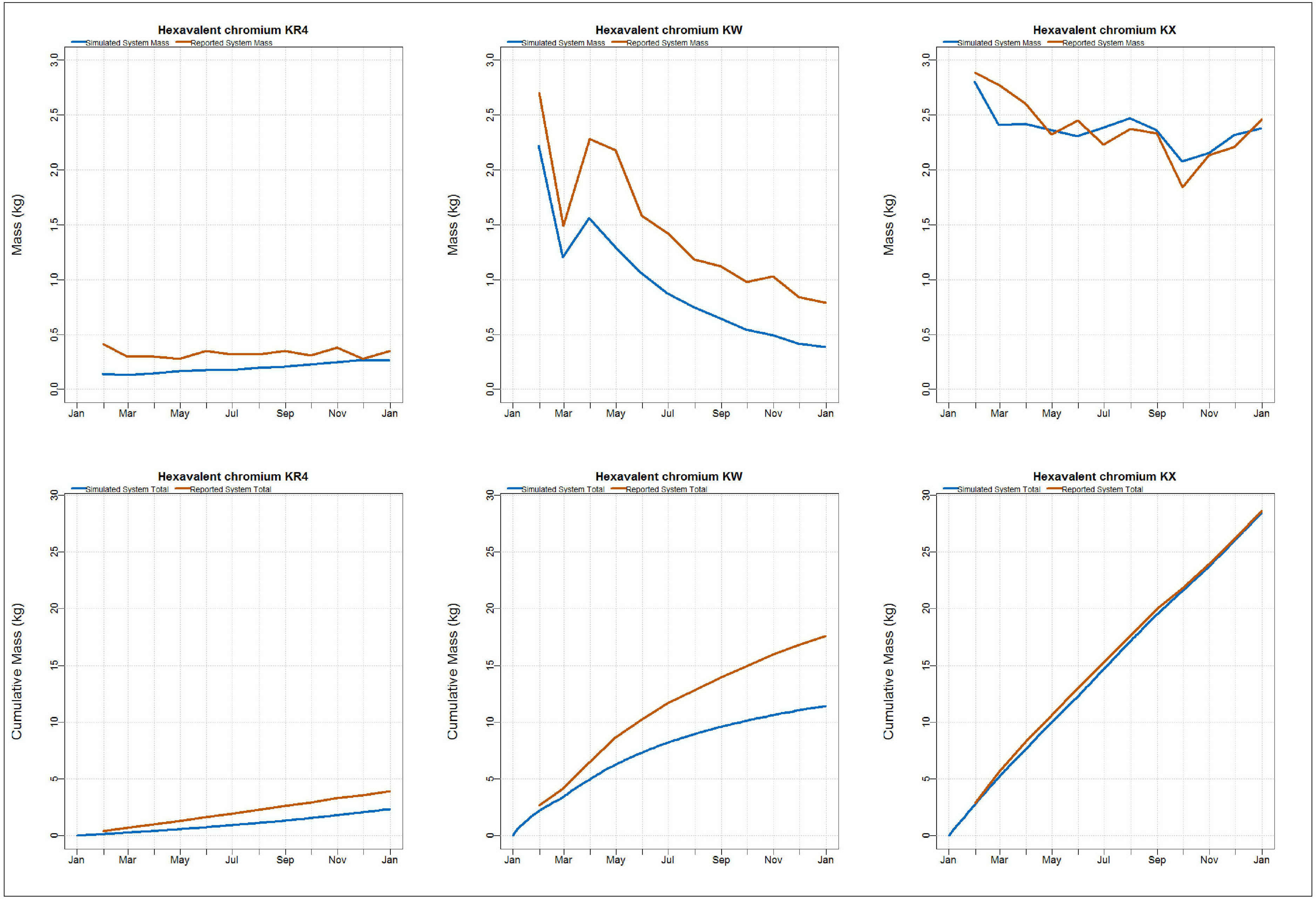


Figure 3-22(f). 2015 100-K Area Groundwater Flow Lines of Capture Zone Overlay with Low River Stage Chromium Plume Contours

Figure 3-23(a). 100-K Area Quantitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River-Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

Figure 3-23(b). 100-K Area Qualitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River-Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test



1 **Figure 3-24. Comparison of Observed to Calculated Hexavalent Chromium Mass Removal (Top Row = Monthly Mass Removal, Bottom Row = Cumulative Mass Removal)**

This page intentionally left blank.

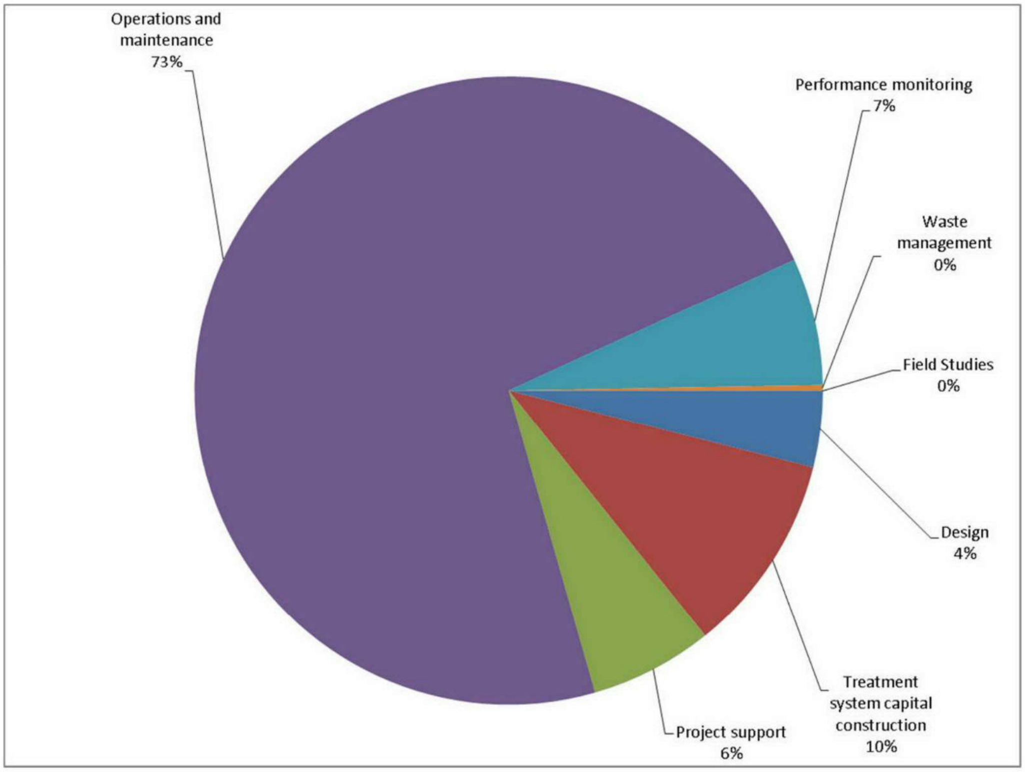


Figure 3-25. KR4 P&T System, 2015 ($1.19 million) Cost Breakdown (by Percentage)

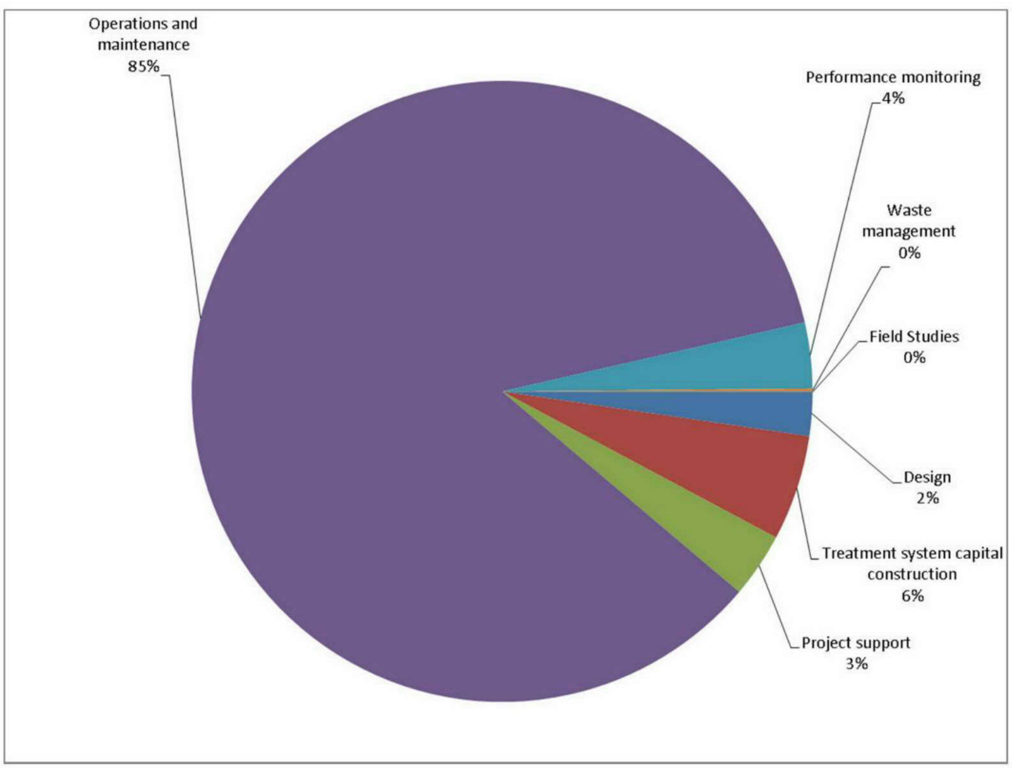


Figure 3-26. KX P&T System, 2015 ($2.24 million) Cost Breakdown (by Percentage)

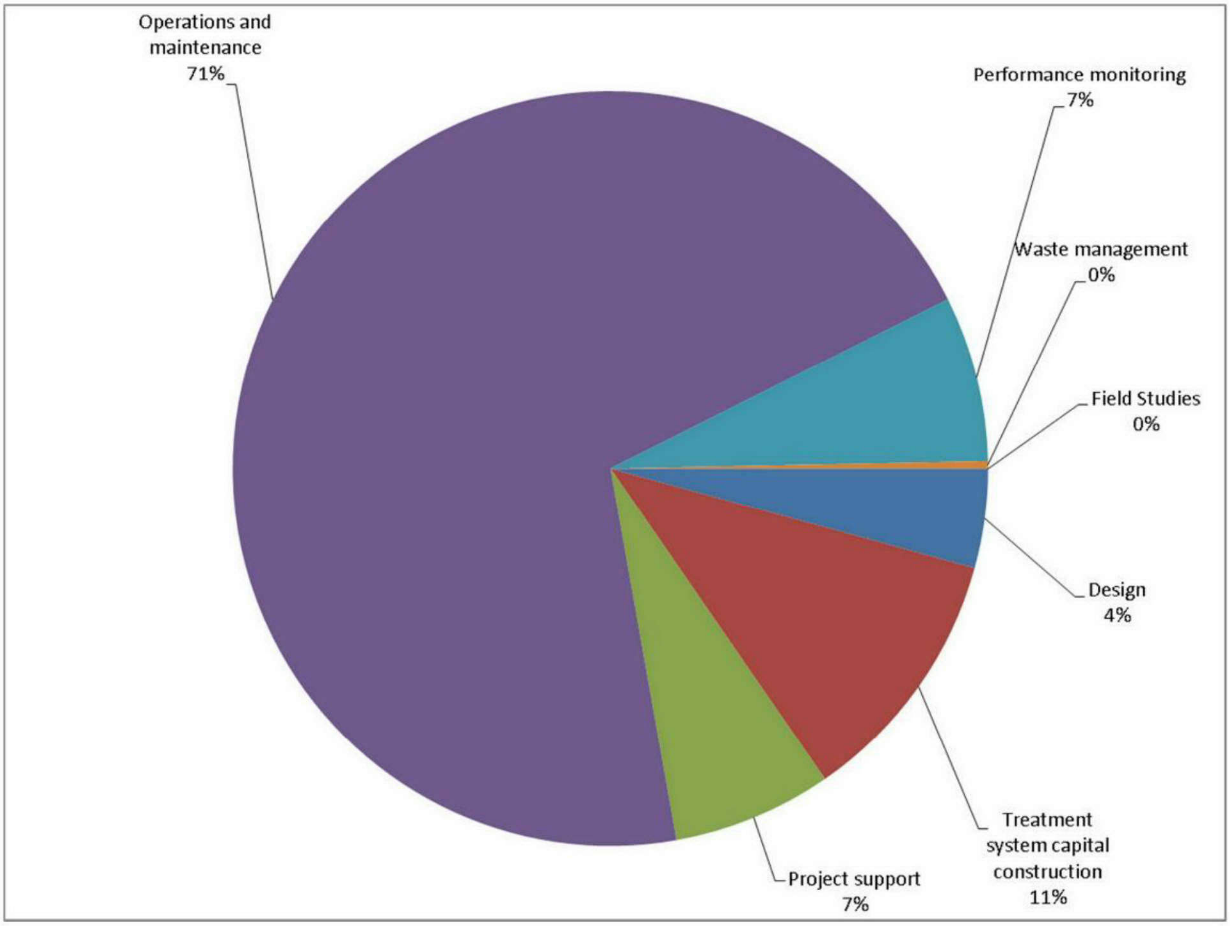


Figure 3-27. KW P&T System, 2015 ($1.11 million) Cost Breakdown (by Percentage)

Table 3-1. 100-KR-4 Groundwater OU Remedial System Well Changes Initiated in 2015

System	Well	Action	Purpose	Status as of December 31, 2015
100-KR4	No changes			
100-KW	No changes			
100-KX	199-K-208	Construct new extraction well	River protection/hydraulic control	In service
	199-K-124A	Realign monitoring well to injection well service	River protection/hydraulic containment	In service

Table 3-1. 100-KR-4 Groundwater OU Remedial System Well Changes Initiated in 2015

System	Well	Action	Purpose	Status as of December 31, 2015
Monitoring Wells	199-K-207	Construct new monitoring well	Tritium plume delineation – 118-K-1	In service
	199-K-209	Construct new monitoring well	Chromium plume delineation – 116-K-2	In service
	199-K-221	Construct new monitoring well	Sr-90 plume delineation – UPR-100-K-1	In service
	199-K-222	Construct new monitoring well	Sr-90 plume delineation – 116-KE-3	In service

Table 3-2. Operational Parameters and System Performance of KR4 P&T System

Total Processed Groundwater	2014	2015
Total amount of groundwater treated (since September 1997 startup) (billion L)	7.3	7.91
Total amount of groundwater treated during CY (million L)	527.0	655.5
Mass of Hexavalent Chromium Removed		
Total amount of hexavalent chromium removed since September 1997 startup (kg)	371.4	375.3
Total amount of hexavalent chromium removed in CY (kg)	5.0	3.9
Summary of Operational Parameters		
Average pumping rate (L/min)	848	1,249
Average hexavalent chromium influent concentration (µg/L)	9.5	6.4
Average hexavalent chromium effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	93.7	82.9
Waste generation (m^3)	0	0
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of Other COCs Detected in Effluent		
Average tritium concentration (pCi/L)	6,835	5,775
Average nitrate concentration (µg/L)	10,295	10,850

Average strontium-90 concentration (pCi/L)	2.5	2.6
Average carbon-14 concentration (pCi/L)	17.5	17.3
Average total chromium concentration (μg/L)	13	1.2
Summary of System Availability		
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,215	8,719
Total availability (%)*	93.8	99.5

* [(total time online) ÷ (total possible run-time)].

COC = contaminant of concern

CY = calendar year

Table 3-3. Flow Rates and Total Run-Times for KR4 P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2015	Total Run-Time[a] (Percent)	Purpose
C5940	199-K-162	KE01	204.5 (54.0)	8760	100%	Extraction
B2803	199-K-116	KE02	151.6 (40.1	8,736	99.7%	Extraction
C5361	199-K-145	KE11	111.6 (29.5)	8,760	100%	Extraction
C3662	199-K-127	KE12	81.7 (21.6)	8,570	97.5%	Extraction
B2807	199-K-120A	KE13	90.1 (23.8)	8,664	98.9%	Extraction
C5360	199-K-144	KE14	155.9 (41.2)	8,760	100%	Extraction
C7698	199-K-198[b]	KE15	73.7 (19.5)	8,664	98.9%	Extraction
C7699	199-K-199[b]	KE16	70.1 (18.5)	8,664	98.9%	Extraction
B2800	199-K-113A	KE21	44.0 (11.6)	8,760	100%	Extraction
B2802	199-K-115A	KE22	58.0 (15.3)	8,760	100%	Extraction
C4117	199-K-129	KE23	38.7 (10.2)	7,800	89.0%	Extraction
B2801	199-K-114A	KE24	167.2 (44.2)	8,760	100%	Extraction
B2808	199-K-121A	KJ1	188 (50)	8,760	100%	Injection
B2809	199-K-122A	KJ2	367 (97)	8,760	100%	Injection
B2810	199-K-123A/ 199-K-124A	KJ3	211 (56)	8,760	100%	Injection
C7150	199-K-179	KJ4	212 (56)	8,760	100%	Injection

Table 3-3. Flow Rates and Total Run-Times for KR4 P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2015	Total Run-Time[a] (Percent)	Purpose
C3663	199-K-128	KJ5	225 (59)	8,760	100%	Injection

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. New extraction wells connected to the KR4 pump and treat system and operational in 2014.

COC = contaminant of concern

CY = calendar year

ID = identification

PLC = programmable logic controller

1

Table 3-4. Operational Parameters and System Performance for KW P&T System

Total Processed Groundwater	2014	2015
Total groundwater treated since January 2007 startup (million L)	2,916.6	3,568
Total groundwater treated in CY (million L)	579.6	651.1
Mass of Hexavalent Chromium Removed		
Total hexavalent chromium removed since January 2007 startup (kg)	220.6	238.2
Total hexavalent chromium removed in CY (kg)	19.4	17.6
Summary of Operational Parameters		
Average pumping rate (L/min)	926.5	1,241
Average hexavalent chromium influent concentration (µg/L)	22	22
Average hexavalent chromium effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	91.4	94.5
Waste generation (m^3)	0	0
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of Other COCs Detected in Effluent		
Average tritium concentration (pCi/L)	1,480	1,373
Average nitrate concentration (µg/L)	23,400	23,033
Average strontium-90 concentration (pCi/L)	0.4	2.0
Average carbon-14 concentration (pCi/L)	--[a]	450

Table 3-4. Operational Parameters and System Performance for KW P&T System

Average TCE concentration (µg/L)	3.8	3.0
Average total chromium concentration (µg/L)	3.1	2.7
Summary of System Availability		
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,504.8	8,712.8
Total availability (%)[b]	97.1	99.5

a. Carbon-14 was not measured in the effluent in 2014. The average influent concentration was 671 pCi/L.

b. Total availability [(total time online) ÷ (total possible run-time)].

COC = contaminant of concern

CY = calendar year

Table 3-5. Flow Rates and Total Run-Times for KW P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2015	Total Run-Time* (Percent)	Purpose
C4670	199-K-132	WE1	20.9 (5.5)	96	1%	Extraction
C5113	199-K-138	WE2	48.4 (12.8)	8,760	100%	Extraction
C5114	199-K-139	WE3	65.8 (17.4)	2,280	26%	Extraction
C5115	199-K-140	WE4	41.3 (10.9)	8,760	100%	Extraction
C6454	199-K-168	WE5	142.5 (37.6)	8,760	100%	Extraction
C6452	199-K-166	WE6	62.9 (16.6)	2,280	26%	Extraction
C6451	199-K-165	WE7	163 (43)	8,760	100%	Extraction
C5112	199-K-137	WE8	98.5 (26)	8,592	98%	Extraction
C7696	199-K-196	WE9	123.5 (32.6)	8,760	100%	Extraction
C7016	199-K-173	WE10	188.6 (49.8)	8,640	99%	Extraction
C8292	199-K-205	WE11	410.8 (108.5)	8,616	98%	Extraction
C5484	199-K-158	WJ1	356.7 (94.2)	8,760	100%	Injection
C8293	199-K-206	WJ2	389.5 (102.8)	8,760	100%	Injection
C7061	199-K-174	WJ3	243.7 (64.3)	8,760	100%	Injection
C7062	199-K-175	WJ4	243.6 (64.3)	8,760	100%	Injection

Table 3-5. Flow Rates and Total Run-Times for KW P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2015	Total Run-Time* (Percent)	Purpose

* Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

CY = calendar year

ID = identification

PLC = programmable logic controller

Table 3-6. Operational Parameters and System Performance for KX P&T System

Total Processed Groundwater	2014	2015
Total groundwater treated since November 2008 startup (million L)	5,773.9	7,361.4
Total groundwater treated in CY (million L)	1,198.8	1,587.5
Mass of Hexavalent Chromium Removed		
Total hexavalent chromium removed since November 2008 startup (kg)	194.3	222.9
Total hexavalent chromium removed in CY (kg)	25.8	28.6
Summary of Operational Parameters		
Average pumping rate (L/min)	2,294	3,038
Average hexavalent chromium influent concentration (µg/L)	21.5	18.4
Average hexavalent chromium effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	96.4	93.2
Waste generation (m^3)	7.2	3.6
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	26.2[a]	0
Number of resin vessel changeouts	0	0
Summary of Other COCs Detected in Effluent		
Average tritium concentration (pCi/L)	1,570	2,487
Average nitrate concentration (µg/L)	13,300	14,967
Average strontium-90 concentration (pCi/L)	2	2.5
Average carbon-14 concentration (pCi/L)	70	65.6
Average total chromium concentration (µg/L)	2.2	3.5
Summary of System Availability		

Table 3-6. Operational Parameters and System Performance for KX P&T System

Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,661.9	8,693.6
Total availability (%)[b]	98.9	99.2

a. The third and fourth vessels in each train of the KX P&T system were loaded with SIR-700 resin in 2014.

b. Total availability [(total time online) ÷ (total possible run-time)].

COC = contaminant of concern

CY = calendar year

Table 3-7. Flow Rates and Total Run-Times for KX P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2012	Total Run-Time (Percent)[a]	Purpose
C7464	199-K-181	XE1	198.1 (52.3)	8,760	100%	Extraction
C7149	199-K-178	XE2	148 (39.1)	8,760	100%	Extraction
C8297	199-K-210	XE3	249.6 (65.9)	8,760	100%	Extraction
C5303	199-K-141	XE4	73.8 (19.5)	8,592	98%	Extraction
C8795	199-K-220[c]	XE5	238.5 (63)	8,736	100%	Extraction
C8295	199-K-208[b]	XE6	223 (58.9)	5,280	60%	Extraction
C5939	199-K-161	XE11	70.3 (18.6)	8,736	100%	Extraction
C5363	199-K-147	XE12	64.1 (16.9)	8,712	99%	Extraction
C4120	199-K-130	XE13	104.5 (27.6)	8,736	100%	Extraction
C5364	199-K-148	XE14	126.8 (33.5)	8,736	100%	Extraction
C4561	199-K-131	XE15	150.3 (39.7)	8,736	100%	Extraction
C5368	199-K-152	XE16	168.6 (44.5)	8,760	100%	Extraction
C5362	199-K-146	XE17	30 (7.9)	8,760	100%	Extraction
C7476	199-K-182	XE18	161.6 (42.7)	8,760	100%	Extraction
C5369	199-K-153	XE31	230 (60.7)	8,760	100%	Extraction
C5370	199-K-154	XE32	233.3 (61.6)	8,760	100%	Extraction
C6172	199-K-163	XE33	212.4 (56.1)	8,760	100%	Extraction
C6746	199-K-171	XE34	232.5 (61.4)	8,688	99%	Extraction

Table 3-7. Flow Rates and Total Run-Times for KX P&T System Extraction and Injection Wells, 2015

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2012	Total Run-Time (Percent)[a]	Purpose
C8299	199-K-212	XE35	200.4 (52.9)	8,664	99%	Extraction
C5937	199-K-159	XJ1	268 (70.8)	8,760	100%	Injection
C5938	199-K-160	XJ2	275.3 (72.7)	8,760	100%	Injection
C6744	199-K-169	XJ3	447.1 (118)	8,760	100%	Injection
C5305	199-K-143	XJ4	226.9 (59.9)	8,760	100%	Injection
C5372	199-K-156	XJ6	445.5 (117.6)	8,760	100%	Injection
C6745	199-K-170	XJ7	520 (137.3)	8,760	100%	Injection
C6386	199-K-164	XJ8	276 (72.9)	8,760	100%	Injection
C7151	199-K-180	XJ9	274.6 (72.5)	8,760	100%	Injection
C6747	199-K-172	XJ10	325.7 (86)	7,392	84%	Injection

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. Extraction well connected to KX pump and treat system and operational in May 2015.

CY = calendar year

ID = identification

PLC = programmable logic controller

Table 3-8. Maximum Contaminant and Co-Contaminant Concentrations for 116-K-2 Trench Area (K North Plume), 2014 and 2015

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
2014				
Hexavalent chromium	40.0	F	11/24/2014	199-K-212
Hexavalent chromium	80.2	UF	2/20/2014	199-K-201
Strontium-90	231	UF	8/21/2014	199-K-200
Tritium	414,000	F	12/9/2014	199-K-207*
Carbon-14	37.2	UF	11/23/2014	199-K-119A
Nitrate	30,800	UF	2/19/2014	199-K-200
Trichloroethene	0.5 (U)	UF	3/31/2014	199-K-212
2015				

Table 3-8. Maximum Contaminant and Co-Contaminant Concentrations for 116-K-2 Trench Area (K North Plume), 2014 and 2015

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
Hexavalent chromium	130	UF	2/10/2015	199-K-207
Hexavalent chromium	97	F	10/16/2015	199-K-207
Strontium-90	199	UF	2/9/2015	199-K-200
Tritium	935,000	UF	8/27/2015	199-K-207
Carbon-14	72.4	UF	2/24/2015	199-K-208
Nitrate	43,800	UF	8/27/2015	199-K-207
Trichloroethene	0.3 (U)	UF	11/30/2015	199-K-200

* Well 199-K-207 was installed in 2014; samples collected during drilling.

Table 3-9. Maximum Contaminant and Co-Contaminant Concentrations for KW Reactor Area, 2014 and 2015

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
2014				
Hexavalent chromium	241	F	12/11/2014	199-K-205
Hexavalent chromium	3,280	UF	1/9/2014	199-K-205*
Strontium-90	56.1	UF	11/21/2014	199-K-34
Tritium	3,050	UF	11/19/2014	199-K-139
Carbon-14	14,300	UF	11/21/2014	199-K-106A
Nitrate	62,900	UF	7/30/2014	199-K-34
Trichloroethene	6.8	UF	11/21/14	199-K-185
2015				
Hexavalent chromium	183	F	1/15/2015	199-K-205
Hexavalent chromium	195	UF	1/6/2015	199-K-205
Strontium-90	33.8	UF	11/6/2015	199-K-34
Tritium	11,700	UF	10/21/2015	199-K-132
Carbon-14	14,200	UF	11/6/2015	199-K-106A
Nitrate	75,300	UF	8/27/2015	199-K-132
Trichloroethene	8.7	UF	5/7/2015	199-K-185

* Well 199-K-205 was installed in late 2013; samples collected during drilling.

1

Table 3-10. Maximum Contaminant and Co-Contaminant Concentrations for KE Reactor Area, 2014 and 2015

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
2014				
Hexavalent chromium	24.6	F	12/11/2014	199-K-220
Hexavalent chromium	520	UF	2/20/2014	199-K-111A
Strontium-90	54.1	UF	8/25/2014	199-K-141
Tritium	39,000	UF	10/13/2014	199-K-202
Carbon-14	6,230	UF	11/5/2014	199-K-203[a]
Nitrate	66,800	UF	5/16/2014	199-K-23
Trichloroethene	4.72 J	UF	11/23/2014	199-K-190
2015				
Hexavalent chromium	250	F	11/3/2015	199-K-111A
Hexavalent chromium	348	UF	2/9/2015	199-K-111A
Strontium-90	4,000	UF	9/23/2015	199-K-222[b]
Tritium	64,500	UF	11/3/2015	199-K-111A
Carbon-14	4,830	UF	8/26/2015	199-K-222[b]
Nitrate	57,100	UF	5/12/2015	199-K-23
Trichloroethene	6.49	UF	11/11/2015	199-K-190

a. Well 199-K-203 was installed in 2014; samples collected during drilling.

b. Well 199-K-222 was installed in 2015; samples collected during drilling.

2

Table 3-11. Cr(VI) 2015 Maximum Concentrations in the 116-K-2 Trench Area (K North Plume)

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-112A	E/C-KR4	—	—	11/6/2015	3.9 (B)	1/6/2015	5.3
199-K-113A	E/C-KR4	7/1/2015	4	11/3/2015	5	11/3/2015	5
199-K-114A	E/C-KR4	7/1/2015	5	10/6/2015	10	10/6/2015	10
199-K-115A	E/C-KR4	7/1/2015	5	10/6/2015	7	10/6/2015	7
199-K-116A	E/C-KR4	7/1/2015	7	11/18/2015	4	7/1/2015	7
199-K-117A	C	7/21/2015	1.5 (U)	10/14/2015	1.5 (U)	1/19/2015	3 (U)
199-K-118A	P	—	—	11/9/2015	1.5 (U)	11/9/2015	1.5 (U)
199-K-119A	P-KR4	5/6/2015	1.5 (U)	11/9/2015	1.5 (U)	11/9/2015	1.5 (U)
199-K-121A	I-KR4	2015 avg.	1.3	2015 avg.	1.3	2015 avg.	1.3
199-K-122A	I-KR4	2015 avg.	1.3	2015 avg.	1.3	2015 avg.	1.3
199-K-123A	I-KR4	2015 avg.	1.3	2015 avg.	1.3	2015 avg.	1.3
199-K-125A	C	5/6/2015	3 (B)	11/9/2015	1.5 (U)	5/6/2015	3 (B)
199-K-126	M	—	—	—	—	4/10/2015	7.9
199-K-128	I-KR4	2015 avg.	1.3	2015 avg.	1.3	2015 avg.	1.3
199-K-129	E/C-KR4	7/1/2015	6	10/6/2015	12	10/6/2015	12
199-K-130	E/C-KX	6/3/2015	10	10/22/2015	12	2/2/2015	15
199-K-133	M	5/29/2015	1.5 (U)	11/6/2015	1.5 (U)	11/6/2015	1.5 (U)

Table 3-11. Cr(VI) 2015 Maximum Concentrations in the 116-K-2 Trench Area (K North Plume)

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-134	M	—	—	11/5/2015	1.5 (U)	11/5/2015	1.5 (U)
199-K-135	M	—	—	11/6/2015	1.5 (U)	11/6/2015	1.5 (U)
199-K-136	M	5/29/2015	1.5 (U)	11/5/2015	1.5 (U)	11/5/2015	1.5 (U)
199-K-143	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-146	E/C-KX	6/3/2015	6	10/22/2015	7	10/22/2015	7
199-K-147	E/C-KX	7/9/2015	12	10/22/2015	15	10/22/2015	15
199-K-148	E/C-KX	7/9/2015	8	11/11/2015	14	11/11/2015	14
199-K-152	E/C-KX	5/12/2015	36	10/27/2015	33 (X)	4/14/2015	37
199-K-153	E-KX	5/12/2015	17	10/22/2015	20	10/22/2015	20
199-K-154	E-KX	5/12/2015	47	11/11/2015	40	3/9/2015	52
199-K-159	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-160	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-161	E/C-KX	5/27/2015	3.5 (B)	11/17/2015	16.3 (X)	11/17/2015	16.3 (X)
199-K-163	E/C-KX	6/3/2015	10	10/22/2015	7	2/2/2015	12
199-K-164	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-169	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-170	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22

Table 3-11. Cr(VI) 2015 Maximum Concentrations in the 116-K-2 Trench Area (K North Plume)

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-171	E/C-KX	5/12/2015	23	11/18/2015	45.8	11/18/2015	45.8
199-K-172	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-179	I-KR4	2015 avg.	1.3	2015 avg.	1.3	2015 avg.	1.3
199-K-180	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-182	E/C-KX	5/12/2015	33	10/22/2015	31	3/9/2015	34
199-K-19	P	7/16/2015	4.8	11/1/2015	2.6 (B)	7/16/2015	4.8
199-K-193	RI/FS	5/7/2015	33.3	11/11/2015	8.5	5/7/2015	33.3
199-K-194	M	5/12/2015	13.6	11/11/2015	8.3	5/12/2015	13.6
199-K-20	C	7/21/2015	3 (U)	10/14/2015	2 (B)	7/21/2015	3 (U)
199-K-201	RI/FS	5/7/2015	80.7	11/12/2015	82	11/12/2015	82
199-K-209	M	5/20/2015	3.2 (B)	11/11/2015	2.9 (B)	5/20/2015	3.2 (B)
199-K-21	P	—	—	10/14/2015	1.5 (U)	4/10/2015	13.9
199-K-22	P	5/6/2015	28.5	11/1/2015	21	5/6/2015	28.5
199-K-37	P	5/12/2015	21.7	11/2/2015	30	11/2/2015	30
699-78-62	M	5/20/2015	1.9 (B)	11/2/2015	1.5 (U)	5/20/2015	1.9 (B)
Effluent annual avg. (KR4)	—	2015 avg.	1.3	2015 avg.	1.3	2015 avg.	1.3

Table 3-11. Cr(VI) 2015 Maximum Concentrations in the 116-K-2 Trench Area (K North Plume)

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
Effluent annual avg. (KX)	—	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
21-M	AT	—	—	10/21/2015	1.5 (U)	10/21/2015	1.5 (U)
21-S	AT	—	—	11/19/2015	1.5 (U)	11/19/2015	1.5 (U)
22-D	AT	—	—	9/30/2015	24	9/30/2015	24
22-M	AT	—	—	9/30/2015	1.5 (U)	9/30/2015	1.5 (U)
23-M	AT	—	—	10/1/2015	1.5 (U)	10/1/2015	1.5 (U)
AT-K-3-D	AT	—	—	10/21/2015	31 (N)	10/21/2015	31 (N)
AT-K-3-S	AT	—	—	10/21/2015	8.4 (N)	10/21/2015	8.4 (N)
AT-K-4-M	AT	—	—	9/30/2015	2.7 (B)	9/30/2015	2.7 (B)
AT-K-4-S	AT	—	—	9/30/2015	1.5 (U)	9/30/2015	1.5 (U)
AT-K-5-D	AT	—	—	10/1/2015	5.4	10/1/2015	5.4
AT-K-5-M	AT	—	—	10/1/2015	2.3 (B)	10/1/2015	2.3 (B)
AT-K-5-S	AT	—	—	10/1/2015	1.6 (B)	10/1/2015	1.6 (B)
C6251	AT	—	—	10/21/2015	1.5 (U)	10/21/2015	1.5 (U)
C6252	AT	—	—	10/21/2015	3.6 (B)	10/21/2015	3.6 (B)
C6253	AT	—	—	10/21/2015	1.5 (U)	10/21/2015	1.5 (U)
C6254	AT	—	—	10/22/2015	1.5 (U)	10/22/2015	1.5 (U)

Table 3-11. Cr(VI) 2015 Maximum Concentrations in the 116-K-2 Trench Area (K North Plume)

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (μg/L)	Date Collected	Unfiltered Concentration (μg/L)	Date Collected	Unfiltered Concentration (μg/L)
C6255	AT	—	—	10/22/2015	5.6	10/22/2015	5.6
C6256	AT	—	—	10/22/2015	13	10/22/2015	13
C6257	AT	—	—	10/2/2015	1.5 (U)	10/2/2015	1.5 (U)
C6258	AT	—	—	10/2/2015	1.5 (U)	10/2/2015	1.5 (U)
C6259	AT	—	—	10/2/2015	1.5 (U)	10/2/2015	1.5 (U)
C6260	AT	—	—	10/1/2015	2.3 (B)	10/1/2015	2.3 (B)
C6261	AT	—	—	10/1/2015	3.2 (B)	10/1/2015	3.2 (B)

Notes: Aquifer tube nomenclature regarding relative depth: D = deepest, M = middle, and S = shallow.

The average (avg.) results for injection wells are Cr(VI) concentrations from treated effluent.

Laboratory qualifiers: U = nondetect (shown with detection limit), B = detected above instrument or method detection limit but below contract-required detection limit, N = spiked sample recovery not within control limits, and X = see hardcopy Sample Data Summary Package for additional information to properly qualify results.

a. High river stage represents the period from April 15 to July 31. Low river stage represents the period from August 28 to December 31.

b. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P = performance, AT = aquifer tube, E/C-KR4 = KR4 extraction/compliance.

— = sample was not collected or analysis was not performed

Cr(VI) = hexavalent chromium

E/C-KX = KX extraction/compliance.

P&T = pump and treat

RI/FS = remedial investigation/feasibility study

Table 3-12. Cr(VI) 2015 Maximum Concentrations KW Reactor Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-106A	M	5/8/2015	1.5 (U)	11/6/2015	1.5 (U)	11/6/2015	1.5 (U)
199-K-107A	M	5/8/2015	9.1	11/5/2015	8.4	5/8/2015	9.1
199-K-108A	M	5/8/2015	3 (B)	11/3/2015	2.8 (B)	2/6/2015	4 (B)
199-K-132	E/C-KW	5/5/2015	12	10/21/2015	11 (N)	5/5/2015	12
199-K-137	E-KW	5/5/2015	21	9/1/2015	17	1/6/2015	24
199-K-138	E/C-KW	6/2/2015	13	11/30/2015	13	8/3/2015	16
199-K-139	E-KW	7/20/2015	12	9/1/2015	12	2/4/2015	14
199-K-140	E-KW	7/6/2015	15	11/19/2015	14 (N)	8/12/2015	25
199-K-158	I (KW)	2015 avg.	1.18	2015 avg.	1.18	2015 avg.	1.18
199-K-165	E-KW	7/6/2015	18	11/5/2015	15	1/6/2015	21
199-K-166	E-KW	7/20/2015	6	9/1/2015	4	1/6/2015	11
199-K-168	E-KW	6/2/2015	20	11/30/2015	17	6/2/2015	20
199-K-173	E-KW	5/5/2015	20	10/12/2015	25	1/15/2015	33.8
199-K-174	I (KW)	2015 avg.	1.18	2015 avg.	1.18	2015 avg.	1.18
199-K-175	I (KW)	2015 avg.	1.18	2015 avg.	1.18	2015 avg.	1.18
199-K-184	RI/FS	5/8/2015	7.5	11/10/2015	5.54 (B)	2/6/2015	11.3
199-K-185	RI/FS	5/7/2015	7.5	11/10/2015	6.7	8/5/2015	7.8
199-K-196	E/C-KW	7/6/2015	14	11/19/2015	14 (N)	1/6/2015	15

Table 3-12. Cr(VI) 2015 Maximum Concentrations KW Reactor Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-204	P	4/17/2015	3 (B)	12/15/2015	1.5 (U)	4/17/2015	3 (B)
199-K-205	E-KW	4/20/2015	70	9/1/2015	31	1/6/2015	195
199-K-206	I-KW	2015 avg.	1.18	2015 avg.	1.18	2015 avg.	1.18
199-K-34	M	5/8/2015	2 (B)	11/6/2015	9.1	11/6/2015	9.1
Effluent annual avg. (KW)	—	2015 avg.	1.18	2015 avg.	1.18	2015 avg.	1.18
17-D	AT	—	—	10/6/2015	1.7 (B)	10/6/2015	1.7 (B)
AT-K-1-D	AT	—	—	10/5/2015	1.5 (U)	10/5/2015	1.5 (U)
C6239	AT	—	—	10/7/2015	1.5 (U)	10/7/2015	1.5 (U)
C6240	AT	—	—	10/7/2015	1.5 (U)	10/7/2015	1.5 (U)
C6241	AT	—	—	10/7/2015	1.5 (U)	10/7/2015	1.5 (U)
C7641	AT	4/15/2015	3 (U)	10/6/2015	1.5 (U)	4/15/2015	3 (U)
C7642	AT	7/24/2015	1.5 (U)	10/6/2015	1.5 (U)	1/12/2015	9.2
C7643	AT	7/24/2015	1.5 (U)	10/6/2015	1.5 (U)	1/12/2015	9

Notes: Aquifer tube nomenclature regarding relative depth: D = deepest, M = middle, and S = shallow.

The average (avg.) results for injection wells are Cr(VI) concentrations from treated effluent.

Laboratory qualifiers: U = nondetect (shown with detection limit), B = detected above instrument or method detection limit but below contract-required detection limit, and N = spiked sample recovery not within control limits

a. High river stage represents the period from April 15 to July 31. Low river stage represents the period from August 28 to December 31.

b. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P = performance, AT = aquifer tube, E/C-KW = KW extraction/compliance

— = sample was not collected or analysis was not performed

Cr(VI) = hexavalent chromium; P&T = pump and treat; RI/FS = remedial investigation/feasibility study

Table 3-13. Cr(VI) Concentrations, KE Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-11	M	—	—	11/3/2015	3.6 (B)	11/3/2015	3.6 (B)
199-K-110A	M	5/8/2015	1.5	11/3/2015	3.6 (B)	11/3/2015	3.6 (B)
199-K-111A	P	5/7/2015	273	11/3/2015	250	2/9/2015	348
199-K-120A	E/C-KR4	7/1/2015	8	10/6/2015	5	7/1/2015	8
199-K-124A	M	5/6/2015	2.8 (B)	—	—	5/6/2015	2.8 (B)
199-K-127	E/C-KR4	7/1/2015	2	10/6/2015	12	10/6/2015	12
199-K-13	M	5/6/2015	1.5 (U)	11/2/2015	1.5 (U)	11/2/2015	1.5 (U)
199-K-141	E-KX	5/27/2015	23.2	12/3/2015	25	2/25/2015	25.8
199-K-142	M	—	—	11/6/2015	1.5 (U)	11/6/2015	1.5 (U)
199-K-144	E/C-KR4	7/1/2015	27	9/1/2015	23	7/1/2015	27
199-K-145	E/C-KR4	7/1/2015	14	10/6/2015	10	2/5/2015	25
199-K-156	I-KX	2015 avg.	1.22	2015 avg.	1.22	2015 avg.	1.22
199-K-157	P	5/8/2015	4 (B)	11/10/2015	5.4	11/10/2015	5.4
199-K-162	E/C-KR4	7/1/2015	6	11/3/2015	3	7/1/2015	6
199-K-178	E/C-KX	5/12/2015	23	10/22/2015	23	10/22/2015	23
199-K-18	C	4/16/2015	7.69 (B)	10/14/2015	4.3	4/16/2015	7.69 (B)
199-K-181	C	7/9/2015	14	10/22/2015	14	10/22/2015	14

Table 3-13. Cr(VI) Concentrations, KE Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-186	RI/FS	5/12/2015	20.6	11/3/2015	9.7	2/6/2015	30.8
199-K-187	RI/FS	5/8/2015	3.2 (B)	11/3/2015	3.6 (B)	11/3/2015	3.6 (B)
199-K-188	P	5/12/2015	11.4	9/10/2015	12	2/6/2015	20
199-K-189	M	5/7/2015	3.74 (B)	11/13/2015	1.7 (B)	2/6/2015	7.6
199-K-190	RI/FS	5/8/2015	10.6	11/11/2015	9.8	2/6/2015	12.6
199-K-191	RI/FS	5/7/2015	3.5 (B)	11/3/2015	5.3	11/3/2015	5.3
199-K-192	RI/FS	5/14/2015	6	11/12/2015	8.1	11/12/2015	8.1
199-K-198	M	7/1/2015	11	10/6/2015	7	7/1/2015	11
199-K-199	M	7/1/2015	9	9/1/2015	6	7/1/2015	9
199-K-200	RI/FS	5/14/2015	4.5	11/30/2015	4.57 (B)	2/9/2015	8.91 (B)
199-K-202	M	7/21/2015	8.5	10/16/2015	5.3	1/19/2015	11.9
199-K-203	M	4/17/2015	27.3	12/15/2015	28	12/15/2015	28
199-K-207	P	—	—	10/16/2015	98	2/10/2015	130
199-K-208	E-KX	4/17/2015	41.4	10/22/2015	12	4/17/2015	41.4
199-K-210	E-KX	5/27/2015	26.4	11/18/2015	24	5/27/2015	26.4
199-K-212	E-KX	5/27/2015	13.3	11/11/2015	15	3/9/2015	18
199-K-220	E-KX	6/3/2015	19	11/23/2015	17	2/2/2015	27
199-K-221	M	6/23/2015	15.1	11/13/2015	10	6/23/2015	15.1

Table 3-13. Cr(VI) Concentrations, KE Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
199-K-222	M	—	—	11/13/2015	14	11/13/2015	14
199-K-23	M	5/12/2015	1.5 (U)	—	—	5/12/2015	1.5 (U)
199-K-32A	P	5/6/2015	14	11/2/2015	14	11/2/2015	14
199-K-32B	M	—	—	—	—	8/10/2015	7
199-K-36	M	5/8/2015	154 (D)	—	—	5/8/2015	154 (D)
18-S	AT	—	—	10/28/2015	1.5 (U)	10/28/2015	1.5 (U)
19-D	AT	—	—	10/20/2015	1.5 (U)	10/20/2015	1.5 (U)
19-M	AT	—	—	10/21/2015	1.5 (UN)	10/21/2015	1.5 (UN)
AT-K-2-D	AT	—	—	10/20/2015	1.5 (U)	10/20/2015	1.5 (U)
AT-K-3-M	AT	—	—	10/21/2015	35 (N)	10/21/2015	35 (N)
C6242	AT	—	—	10/7/2015	1.5 (U)	10/7/2015	1.5 (U)
C6243	AT	—	—	10/7/2015	1.5 (U)	10/7/2015	1.5 (U)
C6244	AT	—	—	10/7/2015	1.5 (U)	10/7/2015	1.5 (U)
C6245	AT	—	—	10/20/2015	1.5 (U)	10/20/2015	1.5 (U)
C6246	AT	—	—	10/20/2015	1.5 (B)	10/20/2015	1.5 (B)
C6247	AT	—	—	10/20/2015	1.5 (U)	10/20/2015	1.5 (U)
C6248	AT	—	—	10/21/2015	1.5 (UN)	10/21/2015	1.5 (UN)
C6249	AT	—	—	10/21/2015	2.2 (BN)	10/21/2015	2.2 (BN)

Table 3-13. Cr(VI) Concentrations, KE Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	High River Stage[a] Maximum Unfiltered Cr(VI)		Low River Stage[a] Maximum Unfiltered Cr(VI)		Annual Maximum Unfiltered Cr(VI)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)
C6250	AT	—	—	10/21/2015	2.2 (B)	10/21/2015	2.2 (B)

Notes: Aquifer tube nomenclature regarding relative depth: D = deepest, M = middle, and S = shallow.

The average (avg.) results for injection wells are Cr(VI) concentrations from treated effluent.

Laboratory qualifiers: U = nondetect (shown with detection limit), B = detected above instrument or method detection limit but below contract-required detection limit, N = spiked sample recovery not within control limits, and D = analyte was identified in an analysis at a secondary dilution factor.

a. High river stage represents the period from April 15 to July 31. Low river stage represents the period from August 28 to December 31.

b. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P = performance, AT = aquifer tube, E/C-KR4 = KR4 extraction/compliance.

— = sample was not collected or analysis was not performed

Cr(VI) = hexavalent chromium

E/C-KX = KX extraction/compliance.

P&T = pump and treat

RI/FS = remedial investigation/feasibility study

Table 3-14. Comparison of River Protection Assessment Results

Assessed Shoreline Lengths, 100-K	2014	2015	Change from 2014 to 2015
Total length of shoreline adjacent to 100-K Area	4,000 m (13,120 ft)		
Length identified as "protected" Percent of shoreline "protected"	3,000 m (9,840 ft) 75% of shoreline	3,600 m (11,810 ft) 90% of shoreline	Additional 600 m (1,970 ft) of shoreline identified as "protected"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	800 m (2,625 ft) 20% of shoreline	300 m (980 ft) 8% of shoreline	500 m (1,640 ft) of shoreline previously identified as "protected (action may be required)" now identified as "protected".
Length identified as "not protected" Percent of shoreline "not protected"	200 m (655 ft) 5% of shoreline	100 m (330 ft) 2% of shoreline	100 m (330 ft) of shoreline previously identified as "not protected" now identified as "protected"

Table 3-15. Breakdown of KR4 P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)															
	2000	2001[a]	2002[b]	2003	2004	2005	2006	2007	2008	2009[c,d]	2010[e]	2011	2012	2013	2014	2015
Design	—	96.5	55.2	70.8	163.9	190.8	97.8	187[f]	63.1	157.7	25.4	52.2	(1.7)	0.9	3.3	47.1
Treatment system capital construction	109.1	(0.1)	860.1	379.9	94.2	273.8	1,505.8	2,114.1[g]	8,368.5	6,651.0[g]	3,556.2	1,860.8	350.8[h]	30.7	78.8	123.0
Project support	143.0	188.2	257.8	171.0	211.8	851.9	530.5	489.8	963.0	174.1	77.6	94.3	58.0	109.8	83.9	75.4
Operations and maintenance	538.0	578.6	771.9	789.7	1,118.2	878.6	1,350.8	804.3	916.0	1,619.3	1,418.1	911.8	1,032.9	1,096.0	1,210.0	866.8
Performance monitoring	111.2	122.6	124.6	119.7	83.3	446.3	548.8	395.7	634.9	569.1	928.1	897.9	324.4	156.9	161.0	78.2
Waste management	481.8	367.5	343.3	684.7	475.8	198.3	230.2	458.9[i]	438.2	599.8	266.7	110.6	17.3	0.0	0.0	3.4
Field studies	—	—	—	—	—	—	—	—	—	25.0	653.1	3.0	0.2	(0.0)	0.0	0.0
Totals	**$1,383**	**$1,353**	**$2,413**	**$2,216**	**$2,147**	**$2,840**	**$4,264**	**$4,450**	**$11,384**	**$9,796**	**$6,925**	**$3,931**	**$1,782**	**$1,394**	**$1,537**	**$1,194**

a. 2001 costs were corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

b. 2002 accrual costs were corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

c. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

d. KX P&T system costs prior to startup are included in with 2009.

e. 2010 accrual costs were corrected. The KR4 and KX expense calculations were incorrectly grouped together.

f. Additional design costs were associated with pump and treat expansion.

g. Additional treatment system capital construction costs were associated with new wells and buildings to support pump and treat system expansion.

h. Includes costs for facility modifications to change ion exchange resin from Dowex 21K to ResinTech SIR-700.

i. Additional costs were associated with drilling wastes and resin cleared for shipment and handling.

— = not available

Table 3-16. Breakdown of KX P&T System Costs

Description	Actual Costs (Dollars × 1,000)					
	2010	2011	2012	2013	2014	2015
Design	31.4	21.4	2.8	9.5	46.0	51.5
Treatment system capital construction	22.9	(1.7)	639.9[a]	62.5	462.6	122.9
Project support	77.6	94.3	58.0	161.3	221.8	75.4
Operations and maintenance	1,224.4	1,647.8	1,340.4[b]	1,875.0	1,530.6	1907.1
Performance monitoring	528.9	674.9	324.4	152.0	158.4	76.6
Waste management	579.6	219.1	2.1	0.0	0.0	3.3
Field studies	—	—	—	—	0.0	0.0
Totals	**$2,465**	**$2,656**	**$2,368**	**$2,260**	**$2,419**	**$2,237**

a. Includes costs for facility modifications to change ion exchange resin from Dowex 21K to ResinTech SIR-700.

b. Includes costs for connecting extraction well 199-K-182 to the KX pump and treat system.

— = not available

Table 3-17. Breakdown of KW P&T System Costs

Description	Actual Costs (Dollars × 1,000)								
	2007	2008	2009[a]	2010	2011	2012	2013	2014	2015
Design	13.0	27.7	78.1	11.6	20.0	8.6	20.6	32.4	47.1
Treatment system capital construction	2,187.8	1,088.3	2,301.8	324.3	794.8[b]	(0.4)	30.9	421.7	123.0
Project support	118.9	155.3	174.1	77.6[c]	94.3	58.0	121.0	240.9	75.4
Operations and maintenance	402.4	599.6	758.6	1,149.6[c]	1,041.3	1,055.9[d]	1,217.4	1,251.0	778.7
Performance monitoring	9.7	126.6	215.9	528.9[c]	674.9	324.4	160.0	156.9	78.4
Waste management	405.4	164.3	95.4	207.5[c]	84.0	84.6	0.0	0.0	3.5
Field studies	—	—	—	—	—	—	—	0.0	0.0
Totals	**$3,137**	**$2,162**	**$3,624**	**$2,300**	**$2,709**	**$1,531**	**$1,550**	**$2,103**	**$1,106**

a. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. Includes costs for facility modifications to change ion exchange resin from Dowex 21K to ResinTech SIR-700.

c. Values were incorrectly calculated and later corrected.

d. Includes costs for converting to split train operation and connecting extraction Well 199-K-173 to the KW pump and treat system.

— = not available

This page intentionally left blank.

4 100-NR-2 Operable Unit Remediation

This chapter provides the annual performance report for 100-NR-2 OU groundwater remediation, as required by DOE/RL-2001-27, *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit*. The performance of the apatite PRB is discussed, and an update on the remediation of total petroleum hydrocarbon (TPH)-diesel range (TPH-D) contamination is also provided. Groundwater monitoring data collected during 2015 that are pertinent to the interim remedial action are also provided. Discussion in this chapter includes the following:

- Section 4.1 provides a summary of the 100-NR-2 OU groundwater remedial activities during 2015.
- Section 4.2 describes water-level monitoring and hydrogeologic conditions for the remedial activities.
- Section 4.3 discusses the nature and extent of strontium-90 and TPH-D in the 100-NR-2 OU groundwater.
- Section 4.4 discusses the remediation of strontium-90 contamination.
- Section 4.5 discusses the remediation of TPH-D contamination.
- Section 4.6 presents the 2015 costs for the apatite PRB.
- Section 4.7 and Section 4.8 present the conclusions and recommendations, respectively.

The 100-NR-2 OU is located along the Columbia River, between the 100-KR-4 and the 100-HR-3 OUs (Figure 4-1). The 100-NR-2 OU consists of the groundwater affected by contaminant releases from waste sites and facilities in the 100-N Area. The CERCLA interim action for remediation of groundwater is identified in the interim action ROD (EPA/ROD/R10-99/112). When the interim ROD was issued in 1995, the interim action for remediation of strontium-90 in groundwater was P&T. The 100-NR-2 P&T system operated from 1995 to 2006, when the system was placed into cold-standby status to facilitate a treatability test for construction of an apatite PRB along the 100-N Area shoreline. The authorization for the P&T status change in the 100-NR-2 interim action is documented in Tri-Party Agreement (Ecology et al., 1989) Change Number M-16-06-01, dated February 15, 2006.

The initial apatite PRB was constructed from 2006 through 2008 for the treatability test which placed a 91 m (300 ft) long apatite PRB along the 100-N Area shoreline in accordance with the strontium-90 treatability test plan for the 100-NR-2 OU (DOE/RL-2005-96). The barrier was created by injecting apatite-forming solutions into 16 wells located adjacent to the shoreline, downgradient of the highest strontium-90 groundwater plume contamination. The treatability test results were documented in PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization* and PNNL-SA-70033, *100-NR-2 Apatite Treatability Test FY09 Status: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*).

Based on the treatability test results, the apatite technology showed promise as a remediation option. The Tri-Parties amended the interim action ROD in 2010 to allow for permanent decommissioning of the 100-NR-2 OU P&T system and expansion of the existing PRB from approximately 91 m (300 ft) long to 760 m (2,500 ft) long (EPA, 2010).

4.1 Summary of Operable Unit Activities

The selected interim action remedy to address strontium-90 contamination in 100-NR-2 OU groundwater (EPA, 2010) consists of the following:

- Extend the length of the apatite PRB from 91 m (300 ft) to approximately 760 m (2,500 ft).

  Status: The well network for future apatite-forming solution injections to expand the PRB to 760 m (2,500 ft) was installed and completed in 2010, which included the addition of 146 injection wells and 25 monitoring wells along the 100-N Area shoreline. The wells were installed both upriver and downriver adjacent to the original 16 well 91 m (300 ft) long PRB.

  Future injection of apatite solutions will extend the apatite PRB throughout this network along the 100-N shoreline to intercept the strontium-90 groundwater plume before it reaches the river. Performance on treated portions of the PRB and future injections is discussed in Section 4.4.

- Inject apatite-forming solutions into two 90 m (300 ft) long segments of the expanded barrier well network in accordance with two design optimization studies (DOE/RL-2010-29 and DOE/RL-2010-68, *Jet Injection Design Optimization Study for 100-NR-2 Groundwater Operable Unit*).

  - **Status:** Apatite solutions were injected into 24 wells located southwest and upriver of the original barrier, and into 24 wells located northeast and downriver of the original barrier in 2011 in accordance with DOE/RL-2010-29. These injections extended the apatite barrier by 110 m (360 ft) upriver and 110 m (360 ft) downriver. Performance monitoring was conducted for all three barrier segments (upriver, central [original], and downriver) during 2015 (SGW-56970, *Performance Report for the 2011 Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*).

  Figure 4-2 shows the locations of the 100-NR-2 OU groundwater monitoring wells for 2015 and the location of the apatite PRB in relation to these wells (shown in the inset of the figure). Figures 4-3, 4-4, and 4-5 show the details for the three segments of the apatite PRB that have received apatite treatment to date.

  Jet injection of apatite into the vadose zone along the PRB well network to enhance the existing PRB treated interval has not been conducted.

- Apply one additional round of apatite injections within 5 years of completion of all first-round apatite injections.

  Status: All first-round apatite injections have not yet been completed. Injection of the remainder of the apatite barrier network wells with apatite forming solutions is anticipated during 2017–2018.

- Use monitored natural attenuation.

  Status: Strontium-90 in the aquifer is naturally attenuating through radioactive decay. Groundwater monitoring wells are periodically sampled to assess the ongoing decline in contaminant concentrations within the OU.

- Decommission the existing 100-NR-2 OU groundwater P&T system building and components. The P&T system has not been operated since March 2006.

  Status: The in-well P&T equipment (e.g., pumps) has been removed, and the extraction and injections wells have been returned to routine groundwater sampling schedules. The P&T system buildings and components have not yet been decommissioned. Detailed planning for demolition and decommissioning of the P&T system has been developed with field work planned for 2017.

- Maintain existing ICs.

  Status: Existing ICs include entry restrictions (security), escorts and badging of site visitors, excavation permits, surveillance, posted signs, deed notifications to restrict land and groundwater use (DOE/RL-2001-27). Existing ICs are being maintained.

- Maintain the riprap cover along the shoreline.

  Status: The riprap cover was placed over the groundwater seeps and springs along the shoreline. The existing riprap cover is being maintained.

- Perform periodic groundwater monitoring.

  Status: Performance monitoring of the expanded 311 m (1,020 ft) long PRB continued through 2015. Periodic groundwater monitoring is performed in accordance with approved SAPs and complies with RCRA and CERCLA requirements (Section 4.3).

The selected interim action remedy to address TPH contamination in 100-NR-2 OU groundwater (EPA/ROD/R10-99/112) consists of the following:

- Remove petroleum hydrocarbon (free-floating product) from any groundwater monitoring well.

  Status: Petroleum hydrocarbon contamination as free product was occasionally observed at wells 199-N-17 and 199-N-18. Well 199-N-17 went dry and was taken out of service and decommissioned in 2002. Removal of petroleum hydrocarbon light nonaqueous-phase liquid (LNAPL) from well 199-N-18 continued in 2015.

4.2 Water-Level Monitoring

Groundwater generally flows northwest toward the Columbia River beneath the 100-N Area. In March 2015, the predominant direction of flow was toward the northeast, parallel to the river (Figure 4-6), due to unusually high river stage for that time of year. The magnitude of the difference in groundwater hydraulic head across the 100-N Area in March 2015 was about 1 m (3.3 ft) (Figure 4-6). Groundwater flow in 2015 continued to be influenced by groundwater extraction and injection through wells installed in the southwestern portion of the 100-N Area as part of the KX P&T remediation system for the 100-KR-4 OU (Chapter 3). A groundwater mound approximately 1 m (3.3 ft) high surrounding the KX P&T system injection wells creates local radial flow.

Groundwater flow in the 100-NR-2 OU is influenced by the Columbia River stage. The river stage can change daily (±1.5 m [5 ft]) and seasonally (±2.4 m [7.8 ft]) for sustained periods, which affects the saturated zone thickness and may create temporal flow reversals (Section 1.1 of PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*). The river is controlled by releases of water at Priest Rapids Dam upstream from the 100-N Area. Figure 4-7 compares the estimated river stage at the 100-N Area derived from water elevation data from Priest Rapids Dam (using regression analysis provided in ECF-Hanford-13-0028, *Columbia River Stage Correlation for the Hanford Area)* and water levels recorded from the AWLN station in well 199-N-146 for 2015. As shown in Figure 4-7, the groundwater elevation in well 199-N-146 (100-N Area AWLN station located closest to the 100-NR-2 OU river shoreline) is similar to the river elevation at the 100-N Area. The estimated average river stage at the 100-N Area for 2015 was 118.34 m (388.2 ft) amsl derived from water-elevation data from Priest Rapids Dam compared to 118.52 m (388.7 ft). amsl from water-level measurements from 199-N-146.

Since well 199-N-146 is on the AWLN, the water-level elevation in this well can be used to represent river elevation along the 100-N Area shoreline. The seasonally high river stage normally observed in May through July did not occur in 2015 because of to low rainfall and snowfall totals during the winter of 2014–2015.

Wells on the river shoreline respond very quickly to changes in river levels, and the response is delayed in wells further inland from the river. It can take several days before a change in river level has an effect on wells further inland; however, unless the river level remains high or low for several days or more in a row, the effect may not have propagated inland to a distance that would be noticeable at inland locations. This effect is due to the relatively low permeability of the saturated Ringold Formation sediment that comprises the unconfined aquifer beneath most of the 100-N Area.

The 2015 hydrographs for three 100-N Area monitoring wells are provided in Figure 4-8; the locations of the wells are shown in Figure 4-2. Well 199-N-146, on the 100-N Area shoreline approximately 2 m (6.5 ft) inland from the river, has the most variable (and responsive) water-level elevation graph because it is highly influenced by nearby river-level changes (see comparison to river stage in Figure 4-7). Wells 199-N-3 and 199-N-72 (approximately 107 and 762 m [351 and 2,500 ft], respectively, from the river) have much smoother hydrographs. River-level changes influence these wells more gradually and with delayed responses compared to well 199-N-146. However, the effects of high and low river-stage influences are also visible at the inland wells (Figure 4-8). Table 4-1 provides the average water levels in these three wells for days representing low and high river stage.

In May 2015, the water level in well 199-N-146 (and inferred river stage) increased by approximately 0.99 m (3.3 ft). Water levels in well 199-N-2, 170 m (557.7 ft) from the river, increased approximately 0.18 m (0.6 ft), with a lag time of approximately 21 days (Figure 4-9). Water levels in well 199-N-50, 425 m (1,394.4 ft) from the river, increased approximately 0.34 m (1.2 ft) and had a shorter lag time than well 199-N-2. The water table at well 199-N-50 appears to respond more quickly than at well 199-N-2, which is located closer to the river. This suggests that the saturated formation between the river and well 199-N-50 is more permeable than between the river and well 199-N-2.

Vertical hydraulic gradients are difficult to measure in the unconfined aquifer at the 100-NR-2 OU. The differences in water levels in well pairs 199-N-81/199-N-70, 199-N-119/199-N-121, and 199-N-182/199-N-184 show a consistent upward gradient at the most inland well pair (199-N-81/199-N-70) and upward/downward gradient at well pair 199-N-119/199-N-121 which are close to the River. Negligible water elevation difference is observed in the limited water-level measurements available for 199-N-182 and 199-N-184 which were constructed in 2011. The largest difference was 0.05 m (1.97 in.), recorded in the 199-N-81/199-N-70 well pair during 2015. The screen depths differ by approximately 5 to 6 m (16.4 to 19.7 ft) corresponding to an upward gradient of approximately 8.3×10^{-3} m/m.

4.3 100-NR-2 Operable Unit Groundwater Contaminants

The following discussion summarizes the results of 2015 groundwater monitoring in the 100-NR-2 OU. Wells and constituents were monitored in 2015 in accordance with the following documents:

- DOE/RL-2001-27, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, Rev. 1

- DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, as modified by the following:
  - TPA-CN-353, *Change Notice for Sampling and Analysis Plan for Aquifer Sampling Test Tubes, DOE/RL-2009-59, Rev. 1*

The following subsection describe the analytical monitoring results for strontium-90 and TPH-diesel range in groundwater which are the contaminants being remediated through the 100-NR-2 OU interim actions. Results for these and other contaminants of interest also are summarized in the Hanford Site annual groundwater monitoring report (DOE/RL-2016-09).

4.3.1 Strontium-90

The primary source of the strontium-90 contamination in the subsurface of the 100-N Area was liquid waste disposal to the 116-N-1 and 116-N-3 waste sites. The size and shape of the strontium-90 plume changes very little from year to year, except near the apatite PRB. The plume extends from beneath the 116-N-1 and 116-N-3 waste sites to the Columbia River at concentrations above the DWS (8 pCi/L) (Figure 4-10). The highest concentration portion of the strontium-90 groundwater plume (i.e., the area with concentrations exceeding 800 pCi/L) primarily underlies the 116-N-1 Trench and extends near the shoreline. Concentrations also exceed 800 pCi/L in one well beneath the 116-N-3 Crib. The lateral distribution of the groundwater plume with concentrations between 8 and 800 pCi/L is found peripheral to the highest concentration, in a distribution consistent with historical radial flow away from the two waste sites and elongated toward the river parallel to the 116-N-1 waste site.

Because strontium-90 adsorbs strongly to sediment grains, the majority of the strontium-90 remaining in the subsurface in the 100-N Area is in the vadose zone above the aquifer. Residual strontium-90 contamination in the 100-N Area is primarily adsorbed to sediments in the lower vadose zone and upper portion of the unconfined aquifer. Approximately 99 percent of the strontium-90 is adsorbed, and 1 percent remains in solution in the groundwater (DOE/RL-2008-46-ADD5, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units*). Although primarily adsorbed, some strontium-90 is remobilized by seasonal water-level increases that release strontium-90 from sediments not usually in contact with groundwater (PNNL-16891).

The high sorption (i.e., a high distribution coefficient) of strontium-90 also causes its rate of transport in groundwater toward the Columbia River to be considerably slower than the groundwater flow rate. The relative velocity of strontium-90 compared to that of groundwater is approximately 1 to 100 (PNNL-19572).

The highest strontium-90 groundwater concentration detected at 100-NR in 2015 was 13,600 pCi/L in a sample from 199-N-67, which is downgradient of the 116-N-1 Trench. Because of strontium-90's low mobility in groundwater, high strontium-90 concentrations (greater than 150 pCi/L) are expected to be limited to the very upper portion of the aquifer. The low water elevation in this area ranges from 116.8 m (383.1 ft) amsl to 117.8 m (386.4 ft) amsl. Strontium-90 was measured at 83.90 pCi/L in 2015 at well 199-N-182, which monitors the lower portion of the unconfined aquifer. The top of the well screen is at 114.8 m (176.5 ft) amsl, which is approximately 2 to 3 m (6.5 to 9.8 ft) below the low water table. Strontium-90 concentrations in monitoring wells screened to monitor below the screen elevation of well 199-N-182 have historically ranged from non-detect to less than 8 pCi/L (with one measurement of 12 pCi/L at well 199-N-69 in 2012). This implies that high strontium-90 contamination above 150 pCi/L in the unconfined aquifer is likely not lower than 3 m (9.8 ft) below the low water elevation of the periodically rewetted zone. Strontium-90 concentration were below the minimum detectable activity in 2015 for wells monitoring the base of the unconfined aquifer.

Strontium-90 concentration trends in monitoring wells near the 116-N-1 waste site show no obvious long-term decline but do show significant variability related to water levels. Figure 4-11 shows strontium-90 concentrations and water levels in well 199-N-67 (located just downgradient of the liquid waste disposal end of the 116-N-1 Trench). When the water table rises, some of the residual strontium-90 adsorbed to sediment in the deep vadose zone is released to groundwater, and concentrations in the groundwater increase. When the water table decreases, strontium-90 resorbs to sediment, and concentrations in the groundwater decrease. Annual concentration peaks are correlated with periods when the water table was higher and saturated the lower vadose zone (Ringold Formation) containing residual strontium-90 contamination. Figure 4-12 shows strontium-90 concentrations and water levels in former extraction well 199-N-105A. From 1996 until 2007, groundwater extraction lowered the water table to a deeper part of the aquifer where strontium-90 concentrations are lower. After extraction ceased, strontium-90 concentration in well 199-N-105A rebounded.

Strontium-90 concentrations, as well as the water table elevation in well 199-N-81 (downgradient of the 116-N-3 Trench), have declined since the late 1990s (Figure 4-13). High water table elevations in 2011 and 2012 caused a slight increase in the strontium-90 concentration that continued into the fall 2015 sampling. The water table elevation has returned to lower elevation from the high water table elevations in 2011 and 2012 and strontium-90 concentrations in well 199-N-81 are expected to stabilize or decline slightly. The positive variation of strontium-90 concentration with water-level changes may be more pronounced at wells nearer to the 116-N-1 waste site because it received a much larger mass of strontium-90 than the 116-N-3 waste site and presumably has more residual strontium-90 in the lower vadose zone. Table 4-2 provides the strontium-90 concentrations in selected monitoring wells and aquifer tubes.

The highest strontium-90 concentrations in groundwater in the near-shore area along the Columbia River were found near the original segment of the apatite PRB and downriver to the northeast (Figure 4-10). This region of the 100-N Area river shore was impacted by highly contaminated effluent during operations of the 116-N-1 waste site. Effluent discharged to the 116-N-1 waste site emerged at the steeply sloping near-shore surface as springs along the shoreline because of the artificially elevated water table (also known as N Springs). This contaminated area has been the focus of increased monitoring and remediation.

Strontium-90 concentrations in aquifer tubes are consistent with those seen in monitoring wells. Concentrations greater than the DWS are present only above approximately 115 m (377 ft) amsl (i.e., the top 2 to 3 m [6.5 to 9.8 ft] of the aquifer); thus, most of the aquifer tubes are screened at this elevation interval. The majority of the aquifer tubes completed above this elevation are in the area where strontium-90 concentrations along the river are known to be the highest. The maximum concentrations in the aquifer tubes during 2015 are shown in Figure 4-10. The maximum strontium-90 concentration during 2015 was 1,680 pCi/L in aquifer tube NVP2-116.0.

The only strontium-90 detections in aquifer tubes outside of the area where the main strontium-90 plume intersects the Columbia River (Figure 4-10) are found upriver at aquifer tube cluster C7934/C7935/C7936. The highest detected strontium-90 concentration at this aquifer tube cluster was 369 pCi/L at C7934. These aquifer tubes are located near the engineered fill around the 1908-N Outfall, on the back side of the N Reactor building. The outfall construction may have created a preferential pathway in the fill for contaminant migration. Potential sources of strontium-90 contamination at this location include the N Reactor building/fuel storage basin, the 1909-N Waste Disposal Valve Pit, the 107-N Basin Recirculating Cooling Facility, the 1304-N Emergency Dump Tank, the 1300-N Emergency Dump Basin, and other associated structures (Section 4.2 of SGW-49370, *Columbia River Pore Water Sampling in 100-N Area, December 2010*). Three new groundwater wells are proposed for installation in this area in 2016. Analytical results for vadose zone and groundwater samples collected during drilling are expected to reduce the uncertainty about the source and extent of the strontium-90 contamination.

Two river shore seeps (100 N SPRINGS 8-13 and 089-1) were sampled in September 2015 (Figure 4-2). The 100 N SPRINGS 8-13 sample location is north of the strontium-90 plume extent and concentrations in the sample were below the minimum detectable activity for strontium-90. 100 N SPRINGS 089-1 is located on the shoreline near aquifer tube N116mArray-4A, and strontium-90 concentration in the seep sample was 16.6 pCi/L.

4.3.2 Total Petroleum Hydrocarbon-Diesel

The primary source of the TPH-diesel groundwater contamination was a 1966 diesel fuel tank spill (UPR-100-N-17) (Figure 4-14). A small, relatively narrow groundwater plume persists downgradient from the spill location to the river. The highest TPH-diesel concentration in groundwater in 2015 was 6,400 µg/L (well 199-N-346), down from 18,000 µg/L in 2014. The current highest detected TPH-diesel concentrations at 100-N is substantial lower than the 2011 and 2010 maximum concentrations (well 199-N-18) of 48,000 and 420,000 µg/L, respectively. Well 199-N-18 is being used for removal of TPH-diesel free product (Section 4.5) and was last sampled in 2011.

The overall reduction in TPH-diesel concentrations in 2012 through 2015 is attributed primarily to the bioventing remediation being conducted for remediation of diesel in the deep vadose zone at UPR-100-N-17. The bioventing pilot test was conducted in 2010 and 2011 (WCH-490, *UPR-100-N-17; Bioventing Pilot Plant Performance Report*), and the full-scale bioventing remediation was initiated in 2012 (Appendix H of DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*) (Section 4.5.1). Introduction of large amounts of air into the vadose zone injection wells contributes to an increased rate of diesel biodegradation and possible reduction in the residual flux to the aquifer. Continued monitoring will indicate whether a long-term groundwater concentration decrease has occurred.

TPH-diesel is also detected in two aquifer tubes located on the river shore immediately adjacent and downgradient of the TPH-diesel plume in groundwater. In 2015, a maximum concentration of 800 µg/L was detected in aquifer tube N116mArray-0A. This is a decrease from the 2014 maximum concentration (2,200 µg/L). River shore seep 100 N SPRINGS 089-1 was sampled in September 2015 for TPH. The TPH concentration was less than 100 µg/L in this seep sample.

The data used to prepare the 2015 TPH plume map include routine groundwater monitoring data and monitoring data for the in situ bioventing project. In 2015, the in situ bioventing project collected groundwater performance monitoring data in January 2015 and July 2015, at high and low water table, respectively. River elevation was higher in January than July due to drought conditions present in most of eastern Washington State in 2015, but lower than the typical seasonal high river stage. The high river stage in January 2015 averaged 118.9 m (390.0 ft) amsl compared to 119.8 m (392.9 ft) amsl during June 2014.

The performance monitoring results quantified petroleum contamination in the diesel to motor oil range (C10 through C36). Routine groundwater samples for TPH-Diesel monitoring were also collected in September. The routine monitoring program analyzes diesel/Bunker C range only (C10 through C28). The extent of the petroleum plumes using April to July and September to December performance monitoring results are shown in Figures 4-15 and 4-16 and are similar in extent to the annual average TPH-diesel plume (Figure 4-14).

4.4 Strontium-90 Remediation

During 2015, the 311 m (1,020 ft) long apatite PRB continued to perform to reduce the flux of strontium-90 contamination in the 100-NR-2 OU groundwater along the majority of the apatite PRB in accordance with the amended interim action ROD (EPA, 2010). Performance monitoring indicated two locations in the apatite PRB with decreased performance in 2015, as described in Section 4.4.1.

The apatite PRB was formed by injecting a high-concentration calcium-citrate-phosphate solution into the aquifer through a network of vertical wells (i.e., the barrier well network). After the solution is injected, biodegradation of the citrate results in formation of apatite, a calcium phosphate mineral ($Ca_5[PO_4]_3[F, Cl, OH]$). Strontium ions (including strontium-90) in groundwater substitute for calcium ions in apatite via cation exchange and eventually become trapped as part of the mineral matrix during apatite crystallization (PNNL-16891, Section 1.3). The strontium-90 is sequestered within the apatite PRB as contaminant-laden groundwater flows through the barrier. The sequestered strontium-90 continues to decay in place within the barrier.

4.4.1 Permeable Reactive Barrier Performance Evaluation

Groundwater samples were collected from performance monitoring wells and aquifer tubes during moderately high river stage in June and during low river stage in September. Table 4-3 compares spring and fall 2015 data to pre-treatment baseline conditions. Table 4-4 lists the monitoring points for the 760 m (2,500 ft) long apatite barrier and indicates which points are being used to monitor the three treated segments of the barrier. Table 4-5 lists the injection wells for the 760 m (2,500 ft) long barrier and indicates which sections have been treated as of 2015.

The central (original) segment of the apatite PRB extends approximately 91 m (300 ft) along the Columbia River shoreline (Figure 4-4). Sixteen injection wells comprise the PRB well network in the central segment, and four performance monitoring wells are located between the river and the barrier wells (Table 4-5). Apatite-forming solutions were injected into the Hanford formation and Ringold Formation over a period of 3 years (from 2006 through 2008).

The 110 m (360 ft) long upriver and downriver segments of the apatite barrier were injected with apatite solutions in fall 2011 (Figures 4-3 and 4-5). The barrier well networks in each of these segments consist of 24 injection wells (Table 4-5). The apatite barrier extensions increased the length of 100-N Area shoreline treated to sequester strontium-90 from 91 to 311 m (300 to 1,020 ft) (SGW-56970). The barrier was expanded in accordance with the design optimization study (DOE/RL-2010-29), which had seven objectives for evaluating barrier implementation and effectiveness. Data from the injections and subsequent performance monitoring are used to evaluate these objectives in SGW-56970.

The original apatite PRB segment has been in place for 7 years, and the upriver and downriver extensions have been in place for 4 years. The objective of the treatability test plan was a 90 percent reduction in strontium-90 groundwater concentrations in the performance monitoring wells (DOE/RL-2005-96, Section 4.4.3). The interim action RDR/RAWP presents a decision flow diagram (included as Figure 4-17 in this report) for evaluating if reinjection of apatite-forming chemicals should be considered based on PRB performance. Based on the decision flow in Figure 4-17, the performance assessment for treated PRB segments are displayed in figures in Sections 4.4.1.1 through 4.4.1.3, using colored circles at each injection well location. The color fill of each circle represent the design injection radius (9 m [30 ft]) to depict the following assessment:

Green – continued Sr-90 reduction

Yellow – Below Target Reduction with increasing trend

Red – Performance Compromised

Green color fill indicates strontium-90 concentrations at the monitoring well meets the target strontium-90 reduction, is less that the DWS, or that continued strontium-90 reduction is observed with no significant increasing trend. Yellow color fill indicates the calculated strontium-90 reduction does not meet the target strontium-90 reduction and there is a significant increasing strontium-90 concentration trend at the monitoring well. Red color fill indicates the calculated strontium-90 reduction does not meet the target strontium-90 reduction, there is a significant increasing strontium-90 concentration trend at the monitoring well, and the injection criteria were not met. Injection criteria includes meeting target injection volumes and phosphate concentrations, and radial distribution of amendment identified in DOE/RL-2010-29. Performance evaluation will continue with ongoing semiannual performance monitoring (high and low river stages) to assess the continued effectiveness of the apatite treatment along the expanded barrier.

4.4.1.1 Original Permeable Reactive Barrier Segment Performance

Following the apatite injections in 2008 in wells in the central (original) segment of the barrier, strontium-90 concentrations declined in the performance monitoring wells (Figure 4-18). The wells showed temporary, higher strontium-90 concentrations immediately following injection of the apatite solution, which had a higher ionic strength than groundwater and temporarily mobilized cations and anions, causing their concentrations in groundwater to increase. Strontium-90 concentrations in performance monitoring well 199-N-123, which are near the upriver end of the central barrier segment, temporarily increased again following injections into the nearby upriver barrier extension wells in 2011. The temporary elevated concentrations have since declined (Figure 4-18).

Strontium-90 concentrations at well 199-N-122 have been trending upwards (Figure 4-18). The fluctuation in strontium-90 concentration depicted in Figure 4-18 is associated with high and low river sampling periods where concentration tend to be lower during high river stage, indicating some dilution from river water with the samples. As of fall 2015, the strontium-90 concentrations were still considerably lower in the performance monitoring wells along the central segment of the barrier than before the injections started in 2006. The percent reduction in strontium-90 concentrations ranged from 76 percent (well 199-N-122) to 95 percent (199-N-123) in the fall (Table 4-3 and Figure 4-19), and 83 percent (199-N-146) to 90 percent (199-N-123 and 199-N-147) in the spring.

Aquifer tubes monitored downgradient of the original PRB segment also show a significant decrease from pre-injection strontium-90 concentrations (Figure 4-20). Tables 4-6 and 4-7 provide the percent reduction in strontium-90 concentrations since 2011 for the original PRB segment monitoring wells and aquifer tubes, respectively. Two of the original PRB segment monitoring wells meet the 90 percent reduction target, and the other two monitoring wells show over 80 percent reduction and no significant trend increase. Additionally, the aquifer tubes downgradient from the original PRB segment continue to show significant strontium-90 reduction and no significant trend increase. The assessment indicates the original PRB segment continues to provide strontium-90 reduction (Figure 4-21).

4.4.1.2 Upriver Permeable Reactive Barrier Segment Performance

In the performance monitoring wells along the upriver barrier extension, the percentage reduction in strontium-90 concentrations in 2015 (the fourth year following the injections) ranged from 40 percent (well 199-N-347) to 97 percent (199-N-348) (Table 4-3 and Figure 4-22) in the fall, and 26 percent (199-N-347) to 95 percent (199-N-348) in the spring. This segment of the barrier forms the furthest upriver portion of the barrier near the outside edge of the strontium-90 groundwater plume. The relatively low percent reduction in 199-N-347 reflects comparison of the low baseline strontium-90 concentration in this well (the strontium-90 concentration was nondetect, and the strontium-90 concentration estimated from gross beta was 7.0 pCi/L) to the low strontium-90 concentration measured during September 2015 performance monitoring (4.4 pCi/L). Both the baseline and the September 2015 sample concentrations are below the DWS (8 pCi/L). Because concentrations in well 199-N-347 are below the DWS, the percent reduction in strontium-90 concentration at this well is not plotted in Figure 4-22. The percentage reduction in strontium-90 concentrations from 2015 low river-stage monitoring for well 199-N-349 was 43 percent (Table 4-3).

The injection volume of apatite chemicals into the injection wells near monitoring well 199-N-349 is provided in Table 4-8. The injection flow rate was not controlled for even flow distribution in all injection wells (SGW-56970) so some wells received in excess of over 50 percent above the target injection volume of 227,000 L (60,000 gal) and others received only about 50 percent of the target injection volume. The large amendment volumes injected in wells upgradient of well 199-N-349 may be an indication of areas of limited radial amendment distribution due to high injection rates.

Strontium-90 concentration trends for the upriver PRB segment are presented in Figure 4-23. Table 4-6 shows the percentage reduction in strontium-90 concentrations since 2011 for the upriver PRB segment monitoring wells. An increasing strontium-90 concentration trend is observed at monitoring well 199-N-349. However, downgradient aquifer tubes (Figure 4-24) show significant strontium-90 reduction and no significant trend increase (Table 4-7).

Strontium-90 concentrations are below the DWS at monitoring well 199-N-347, and the target strontium-90 reduction is being met at the remaining two monitoring wells. The assessment indicates that the portion of the upriver PRB segment near monitoring well 199-N-349 is colored yellow (i.e., below target reduction with increasing trend) and should continue to be monitored to determine if this area should be reinjected. The remaining length of the upriver PRB segment continues to provide strontium-90 reduction (Figure 4-25).

4.4.1.3 Downriver Permeable Reactive Barrier Segment Performance

The downriver extension intercepts higher strontium-90 groundwater concentrations than the upriver extension and had indicated initial successful barrier performance. The percentage reduction in strontium-90 concentrations in 2015 at the performance monitoring wells along the downriver barrier extension ranged from 0 percent (199-N-351) to 86 percent (199-N-353) (Table 4-3; Figure 4-26) in the fall, and 22 percent (199-N-351) to 96 percent (199-N-353) in the spring. The reduction in strontium-90 concentrations during 2015 low river-stage monitoring at well 199-N-351 is a significant decrease from the 54 percent reduction and 87 percent reduction observed in 2014 and 2013, respectively (Figure 4-26). Ongoing monitoring will determine PRB effectiveness at this location.

Strontium-90 concentration trends for the downriver PRB segment monitoring wells (Figure 4-27) show that strontium-90 concentrations at wells 199-N-351 and 199-N-352 have increased to near pre-injection concentrations in 2015 and are increasing at well 199-N-350. Table 4-6 shows the percentage reduction in strontium-90 concentrations since 2011 for the downriver PRB segment monitoring wells. The injection volume of apatite chemicals into the injection wells near the monitoring wells with increasing trends is provided in Table 4-9, and several wells have received less than 30 percent of the target injection volume. Other injection wells received target injection volumes of more than 50 percent above the target injection volumes. The injection flow rate was not controlled for even flow distribution in all injection wells (SGW-56970), contributing to the large contrast in injection volumes that may have resulted in limited radial amendment distribution in these areas of the downriver PRB segment.

Downgradient aquifer tubes for the downriver PRB segment continue to show significant strontium-90 reduction (Table 4-7; Figure 4-28). The assessment indicates that the injection wells treating the portion of the downriver PRB segment monitored by wells 199-N-351 and 199-N-352 and injection wells that received less than 30 percent of the target amendment volume should be considered for reinjection (colored red in Figure 4-29). Other portions of the downriver PRB near well 199-N-350 should continue to be monitored to evaluate if this area should be reinjected. The remaining length of the downriver PRB segment continues to provide strontium-90 reduction.

4.4.1.4 Summary of PRB Performance Evaluation

Table 4-10 summarizes the PRB performance evaluation for each treated PRB segment. The PRB performance evaluation is as follows:

- Total length of treated PRB: 311 m (1,020 ft)
- Green – Continued Sr-90 reduction: 206 m (675 ft)
- Yellow – Below target reduction with increasing trend: 55 m (180 ft)
- Red – Performance compromised: 50 m (165 ft)

4.4.2 Permeable Reactive Barrier Extensions

No additional treatment to expand the PRB occurred in 2015. Activities to expand the treated portion of the PRB by 305 m (1,000 ft) were initiated in 2014, which included refurbishing the injection skids, procuring piping and injection amendment monitoring instrumentation, procuring chemicals and storage tanks, and preparing internal contractor injection plans and work documents. Activities were conducted in 2014 to procure services to emplace apatite within the vadose zone overlapping the treated saturated portion of the PRB.

Rev. 1 of the RDR/RAWP for the 100-NR-2 OU (DOE/RL-2001-27) was issued in September 2014 to carry out the barrier expansion, both in the saturated zone by chemical injection and in the vadose zone by jet injection, and reinjection of previously treated portions of the barrier, if needed. The schedule for the PRB extension in 2014 was based on working within previously disturbed locations outside of any traditional cultural property. However, a boundary revision to an existing traditional cultural property boundary became effective in January 2014, and the boundary revision encompasses the project area. A cultural review of the project activities addressing the requirements of the *National Historic Preservation Act of 1966*, Section 106 process (specifically, 36 CFR 800.3 through 800.5, "Protection of Historic Properties") has deemed the project to have an "adverse effect" on the traditional cultural property, as defined in 36 CFR 800.5(b). As such, work to complete the barrier is dependent upon completion of the *National Historic Preservation Act of 1966*, Section 106 reviews and is subject to schedule delays pending establishment of a memorandum of agreement for the project activities that are deemed to have an adverse effect on the traditional cultural property. Efforts to establish a memorandum of agreement for expansion of the PRB were under way in 2015 and will continue during 2016.

Any activities to perform reinjection of the PRB sections with decreased performance are also subject to the establishing a memorandum of agreement for expansion of the PRB.

4.5 Total Petroleum Hydrocarbon–Diesel Remediation

Throughout its operational history, the N Reactor and support facilities had UPRs of petroleum products. The types of releases included corrosion failure of diesel and fuel oil piping systems, overfill at storage facilities, and spills during fuel transfers. Two of the releases were substantial and resulted in petroleum hydrocarbon contamination through the vadose zone and into the groundwater. Estimates made in reports at the time of operation indicate that up to 39,000 m^3 (1,377,272 ft^3) of soil was contaminated with petroleum hydrocarbons (Section 1.1 of WCH-323, *Sampling and Analysis Instruction for Installation of UPR-100-N-17 Bioremediation Wells and Performance of Bioventing Pilot Tests*). The releases occurred in two general areas and in other isolated areas, and the releases were divided in three groups based on their occurrences. Table 4-11 shows these three groups and the associated releases:

- **Group 1:** Includes releases (UPR-100-N-17) near the 1715-N storage tanks and 166-N transfer areas (166-N Tank Farm). Figures 4-14 and 4-30 show the locations, as well as the location of nearby monitoring well 199-N-183 (replacement for well 199-N-18).
- **Group 2:** Includes releases (UPR-100-N-42) around the 184-N day tank storage facility. Well 199-N-16 was used to monitor this location; however, this well has been decommissioned and a new groundwater monitoring well is planned near this location.
- **Group 3:** Includes miscellaneous other sites.

Only the releases from Group 1 have resulted in persistent groundwater contamination. Remediation continued in 2015 for the residual petroleum hydrocarbon contamination in the vadose zone and groundwater in the 100-N Area.

4.5.1 Vadose Zone

DOE is using in situ bioventing to remediate TPH-diesel contamination identified in the deep vadose zone beneath the UPR-100-N-17 release at the 100-N Area. Oxygen is introduced into the deep vadose zone to promote microbial activity, thus enhancing hydrocarbon degradation. The oxygen stimulates natural, in situ aerobic biodegradation of the TPH-diesel in the deep vadose zone to carbon dioxide and water. Some natural biodegradation of diesel is also occurring in groundwater, as shown by the anomalously low nitrate groundwater concentrations that are coincident with the TPH groundwater plume but within the larger regional nitrate plume in this area (Figure 4-31).

A pilot test for bioventing was conducted from February 2010 through May 2011 to evaluate contaminant removal rates and the distribution of airflow within the vadose contaminated zone. All results of the pilot test are provided in WCH-490.

Data from the bioventing pilot test were used to support the design of a full-scale bioventing system. Full-scale bioventing system operations began at UPR-100-N-17 in December 2012 using two injection wells (199-N-167 and 199-N-172), two vadose zone vapor monitoring wells (199-N-169 and 199-N-171), and eight groundwater monitoring wells (199-N-3, 199-N-19, 199-N-56, 199-N-96A, 199-N-169, 199-N-171, 199-N-173, and 199-N-183) (Appendix H of DOE/RL-2005-93). Groundwater monitoring samples from the eight performance monitoring wells and two aquifer tubes (N116mArray-0A and C6132) were collected in January and July 2015. A third aquifer tube (C6135) that had been sampled in previous years was broken and could not be sampled in 2015. Repair, or replacement, of this aquifer tube is planned for 2016.

Table 4-12 provides the TPH-diesel groundwater concentrations for the eight performance monitoring wells (Figure 4-14). The performance of the full-scale bioventing system during 2015 is provided in

DOE/RL-2015-20, *Annual Operations and Monitoring Report for UPR-100-N-17: March 2014-February 2015* and DOE/RL-2016-34, *Annual Operations and Monitoring Report for UPR-100-N-17: March 2015 – February 2016.*

Semiannual performance monitoring (high and low river stages) will continue for the bioventing system in 2016. Ongoing monitoring will determine the continued effectiveness of the bioventing remediation for the TPH-diesel plume. Installation of a new well upriver and upgradient of the TPH petroleum plume is planned in 2016 to define a lateral upriver boundary of the TPH plume. Soil samples will be collected to characterize residual petroleum contamination remaining in the deep vadose zone beneath the remediated 100 N 84:2 waste site.

4.5.2 Groundwater

The groundwater containing the TPH-diesel plume, also associated with the UPR-100-N-17 release, is being remediated to remove remaining free product. The CERCLA interim action for remediation of TPH-diesel in groundwater is identified in the interim action ROD (EPA/ROD/R10-99/112). The interim action ROD specifies that petroleum hydrocarbons (free-floating product) will be removed if observed in a monitoring well.

If present as LNAPL (or free product), the TPH-diesel in groundwater is found in the shallowest portion of the aquifer or floating on top of the water table (Section 4.4 of DOE/RL-2011-25). Removal of free product from well 199-N-18 continued in 2015 in accordance with the interim action ROD (EPA/ROD/R10-99/112). The diesel is removed using a polymer "smart sponge" that selectively absorbs petroleum products from the groundwater within the well. Approximately every 2 months, two sponges are lowered to the surface of the aquifer in well 199-N-18 and left to soak up the diesel. The sponges are weighed prior to placement in the well and again after removal. The weight difference between the two measurements is the amount of diesel fuel removed from the well. In 2015, 1,050 g of diesel were removed from 199-N-18 (Table 4-13). Removal of petroleum product from this well will continue in 2016.

Table 4-14 provides the TPH-D concentrations in the known area of the diesel plume for selected sampled wells and aquifer tubes (Figure 4-14). Table 4-15 provides the TPH-D concentrations for the adjacent upriver apatite barrier extension injection and performance monitoring wells

Comparison of TPH-diesel range sampling data to water levels shows that wells sampled during higher water levels had lower concentrations than when sampled during low water levels. As a result, concentration decreases that occurred in 2011 may have been due, in part, to this effect because most of the wells were sampled during high water levels. The wells sampled in 2015 during lower water levels had higher diesel concentrations compared with concentrations reported during higher water levels.

4.6 100-NR-2 Apatite Permeable Reactive Barrier System Costs

This section summarizes the costs for the 100-NR-2 groundwater remediation for 2015. The primary categories of expenditures are described as follows:

- **Capital design:** Includes design activities to construct the PRB and designs for system expansion.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, well injections, and modifications to the PRB.
- **Project support:** Includes project coordination-related activities and technical consultation, as required, during the course of the system design, construction, acceptance testing, and operation.

- **O&M:** Represents facility supplies, labor, and craft supervision costs associated with maintaining the former P&T system.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis.
- **Waste management:** Includes the cost for the management at the 100-NR-2 OU in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes.
- **Barrier maintenance:** Includes costs for maintenance of the PRB, including well injections and modifications to the PRB.

The 2015 cost breakdown for the 100 NR-2 groundwater remediation systems is presented in Table 4-16 and Figure 4-32. The total 2015 remedial action costs were $1,139,000. In 2015, costs were only incurred for performance monitoring (85 percent) and project support (15 percent).

4.7 Conclusions

Conclusions for the 100-NR-2 OU are as follows:

- **RAO #1:** Protect the Columbia River from adverse impacts from the 100-NR-2 OU groundwater so designated beneficial uses of the Columbia River are maintained.

  Results: The PRB captures strontium-90 contamination moving in groundwater along the section of the 100-N Area shoreline with the highest historical groundwater contamination. Apatite solutions were injected in wells of the central (original) barrier segment from 2006 to 2008 and in wells of the upriver and downriver segments in 2011. Strontium-90 concentrations in some monitoring wells near the apatite PRB temporarily increased in response to the apatite injections. The concentrations in the majority of the monitoring wells in 2015 were lower than preinjection levels by at least 90 percent. However, in 2015 concentrations of strontium-90 have increased in some of the monitoring wells, and are close to preinjection levels in two monitoring wells. DOE plans to expand the PRB in the future.

  The TPH-diesel plume bioremediation and free-product removal continues to reduce the contaminant mass in groundwater and the lower vadose zone that could eventually affect the river.

- **RAO #2:** Protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants in the unconfined aquifer.

  Results: The P&T system was not effective at removing strontium-90 from the groundwater because strontium-90 strongly adsorbs to sediment grains; therefore, the P&T system was placed in cold-standby status on March 9, 2006.

  The apatite PRB was installed along the section of the 100-N Area shoreline with the highest historical groundwater contamination. The injection design provides emplacement of sufficient apatite in the PRB to sequester the strontium-90 flux to the river for the duration needed for the upland strontium-90 groundwater contamination to naturally decay.

  Smart sponges deployed in well 199-N-18 removed 1,050 g of TPH-diesel free product in 2015.

  A full-scale bioventing system for remediation of TPH-diesel in the deep vadose zone near waste site UPR-100-N-17 was implemented in December 2012 and continued to operate in 2015. The performance evaluation for 2015 is documented in separate reports (DOE/RL-2015-20 and DOE/RL-2015-34).

- **RAO #3:** Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater.

Results: A 311 m (1,020 ft) long apatite PRB is installed near the Columbia River shoreline. The remainder of the planned PRB extension to approximately 760 m (2,500 ft) will be performed in the future.

Three other types of strontium-90 remediation technologies were tested for potential use in the 100-NR-2 OU in addition to the apatite PRB. Passive infiltration did not prove to be a viable method for emplacement of apatite-forming chemicals along the 100-N Area shoreline. Jet injection tests showed that the technology could effectively place apatite or apatite-forming chemicals into the upper vadose zone with good coverage. Phytoextraction has the potential to remove strontium-90 from the shoreline area, as demonstrated by greenhouse and laboratory (growth chamber) studies of strontium-90 uptake, and field studies in a contaminant-free location at the 100-K Area. No additional work on these technologies occurred in 2015.

Technologies for remediation of strontium-90 are being evaluated in the RI/FS report for the 100-NR-1 and 100-NR-2 OUs (DOE/RL-2012-15, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*).

- **RAO #4:** Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat, in general, and prevent adverse impacts to cultural resources and threatened or endangered species.

  Results: The interim remedial action ROD (EPA/ROD/R10-99/112) establishes ICs that must be implemented and maintained throughout the interim action period. These provisions include the following:

  – Access control and visitor escorting requirements

  – Maintain signs prohibiting public access (new signs were placed along the river and at major road entrances at each reactor area)

  – Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)

  – Regulatory agency notification of any trespassing incidents

4.8 Recommendations

Recommendations for the 100-NR-2 OU are as follows:

- Continue to monitor strontium-90 concentrations in the performance monitoring wells for the expanded apatite PRB.

- Continue apatite barrier expansion along the currently untreated portions of the shoreline and evaluate portions of the treated barrier for reinjection; reinjection is recommended for portions of the downriver treated segment of the PRB where strontium-90 have increased to pre-injection concentrations if this condition persists in future monitoring. Recommendations for implementing future injections as learned from the 2011 barrier expansion (SGW-56970) include the following:

  – Design the sequence of injection wells to allow monitoring of injection solution distribution laterally between the barrier injection wells during injections. Design the sequence of injection wells to minimize hydraulic interference of injected solution volumes and maximize the lateral distribution of the injection solutions. Monitor adjacent apatite barrier network wells during injections (field parameters, especially conductivity, and phosphate) to determine rate and radial extent of dispersion. If feasible, inject in every third well simultaneously at a given target depth.

Inject apatite-forming solution in wells adjacent to injected wells only after the 7-day reaction period has elapsed.

- During injection operations, discontinue or reduce injections in wells that have received the target injection volume, after monitoring indicates adequate lateral distribution of solution, and continue injecting remaining wells until the target volume has been injected.
- Inject shallow wells during high river stage periods, typically during spring or early summer, to improve placement of apatite in the shallower aquifer zone.

- Collect groundwater samples to evaluate the vertical distribution of TPH-diesel in the aquifer and the locations and thicknesses of free product at the top of the water table. Continue to remove TPH-diesel free product from well 199-N-18 using the smart sponge technology. Evaluate the optimal time interval for change out of the sponge technology.
- Continue to evaluate the extent of possible shoreline water quality impacts related to the diesel spill that occurred in about 1966 (UPR-100-N-17). Aquifer tubes at the upstream end of the aquifer tube array and groundwater monitoring wells within the TPH-diesel plume will continue to be sampled for TPH-diesel and related contaminants.

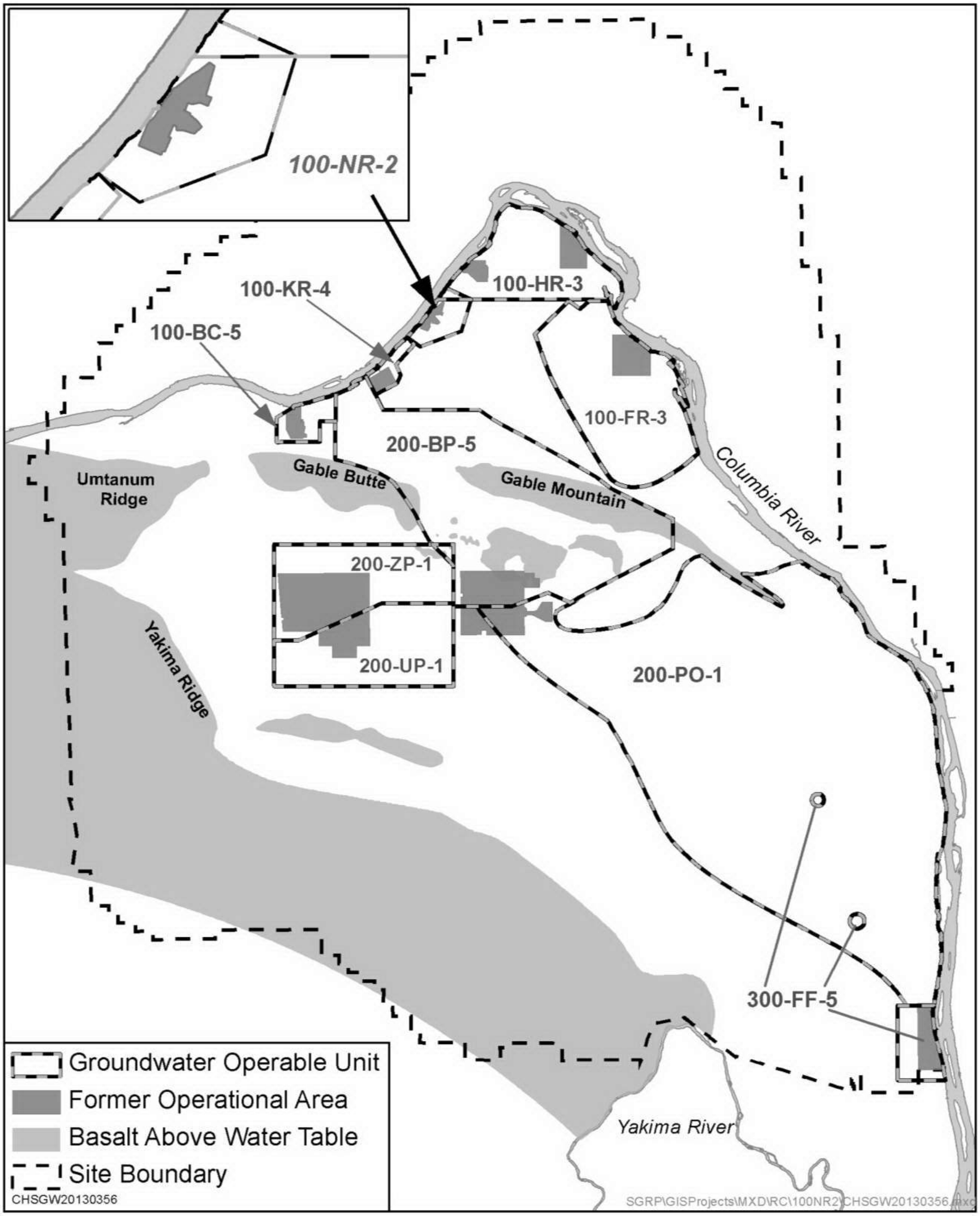


Figure 4-1. Location of the 100-NR-2 OU

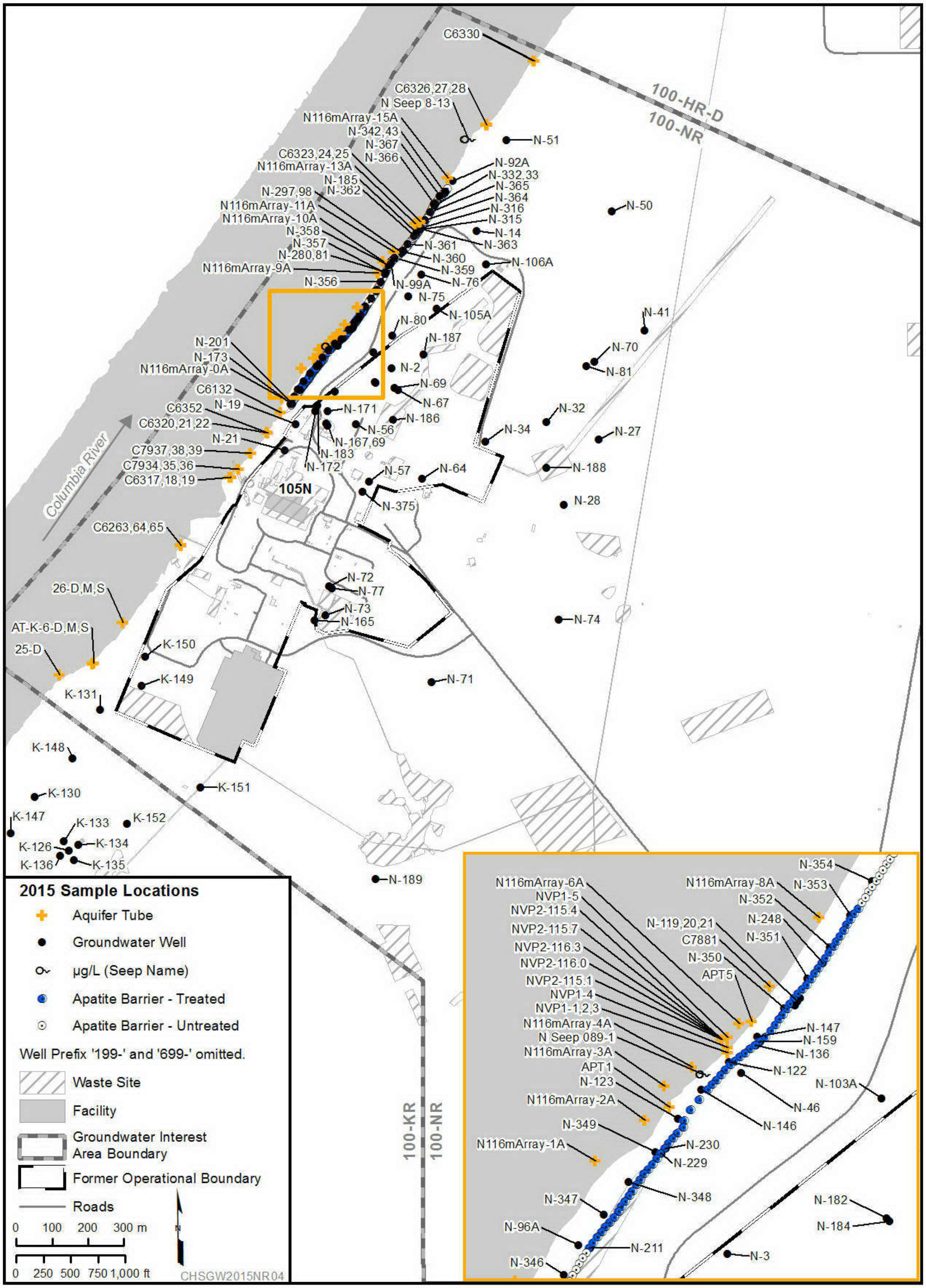


Figure 4-2. Locations of Wells in the 100-N Area

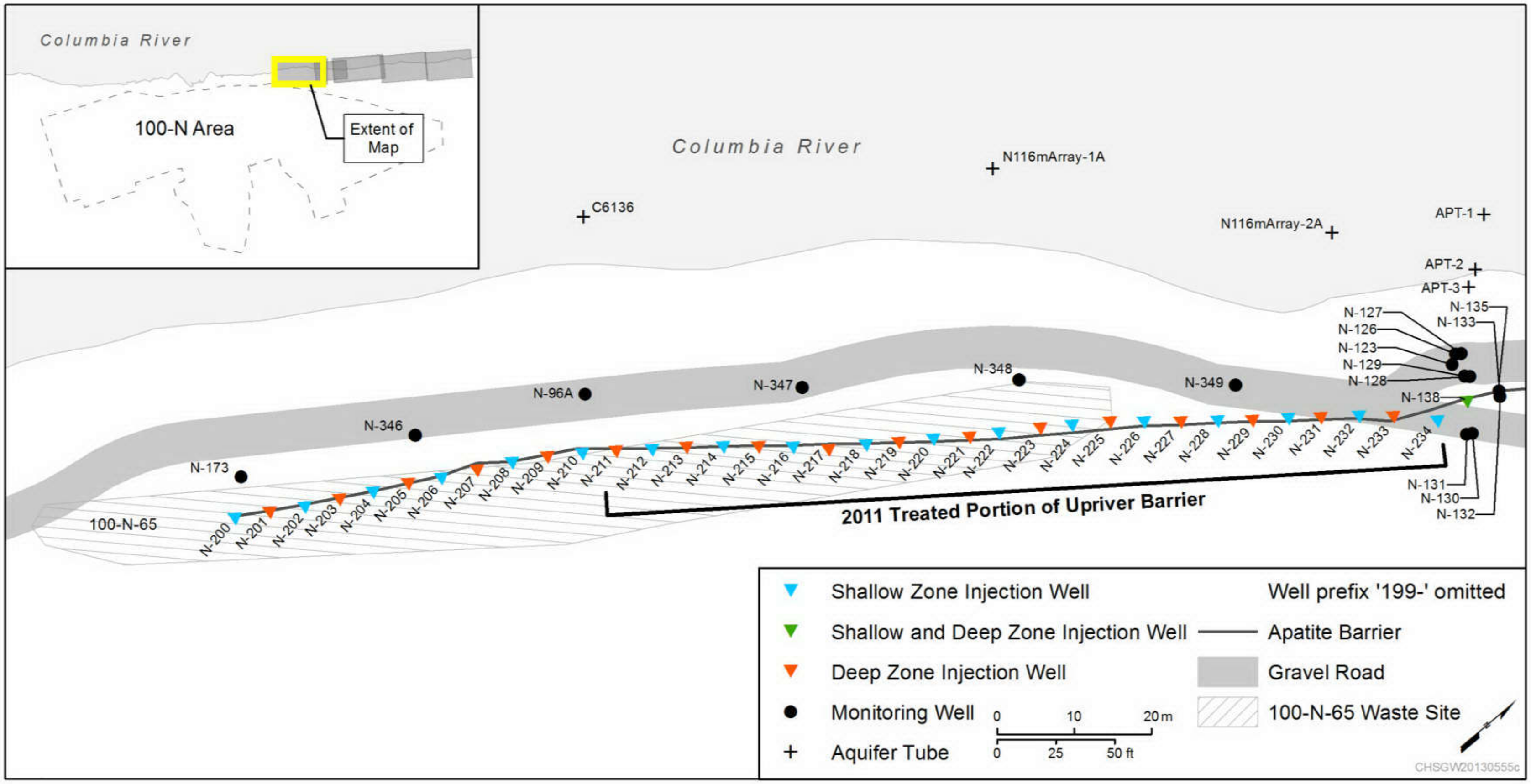


Figure 4-3. Upriver Extension Apatite Barrier Monitoring Wells and Aquifer Tubes along the Columbia River Shoreline

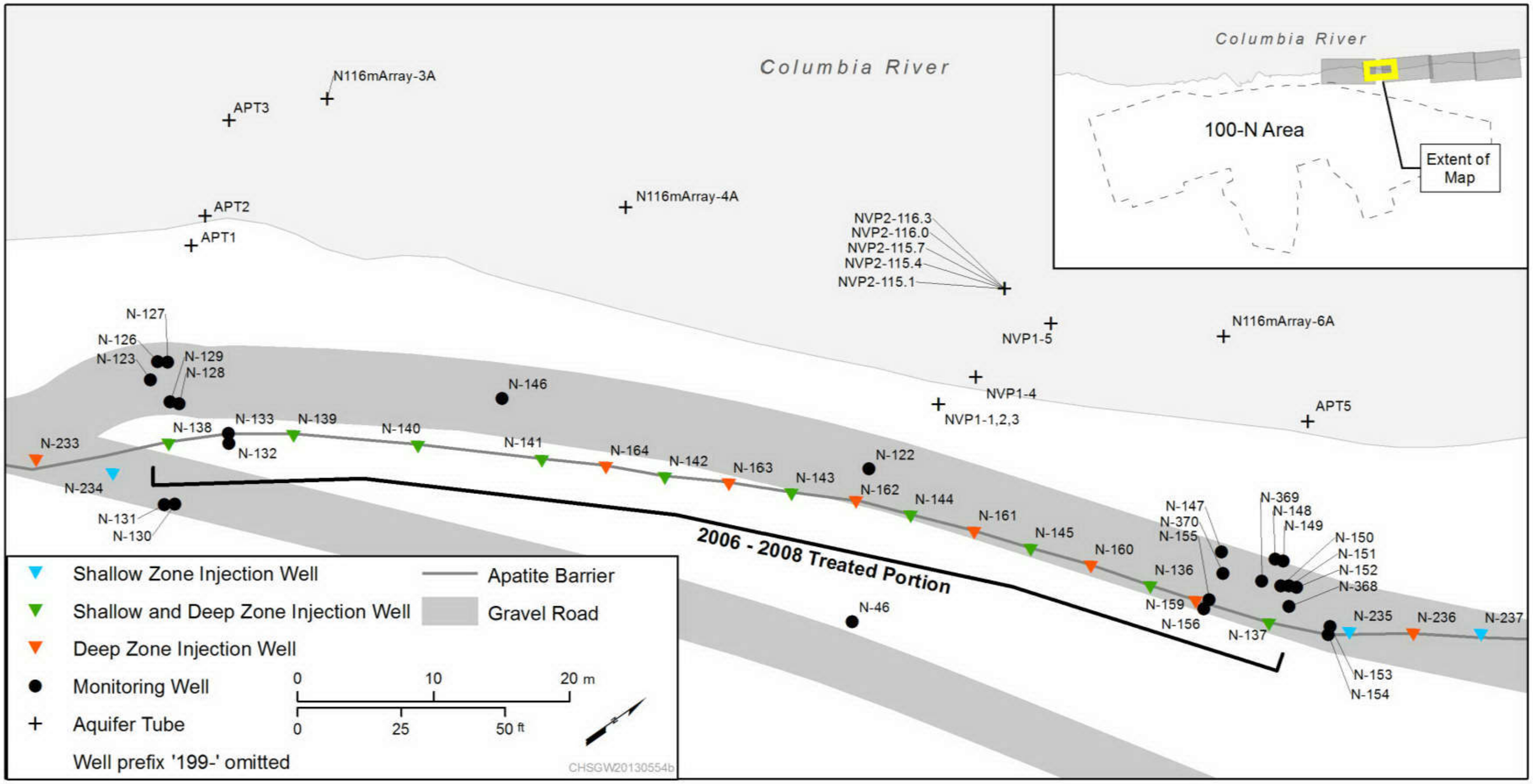


Figure 4-4. Central (Original) Apatite Barrier Monitoring Wells and Aquifer Tubes along the Columbia River Shoreline

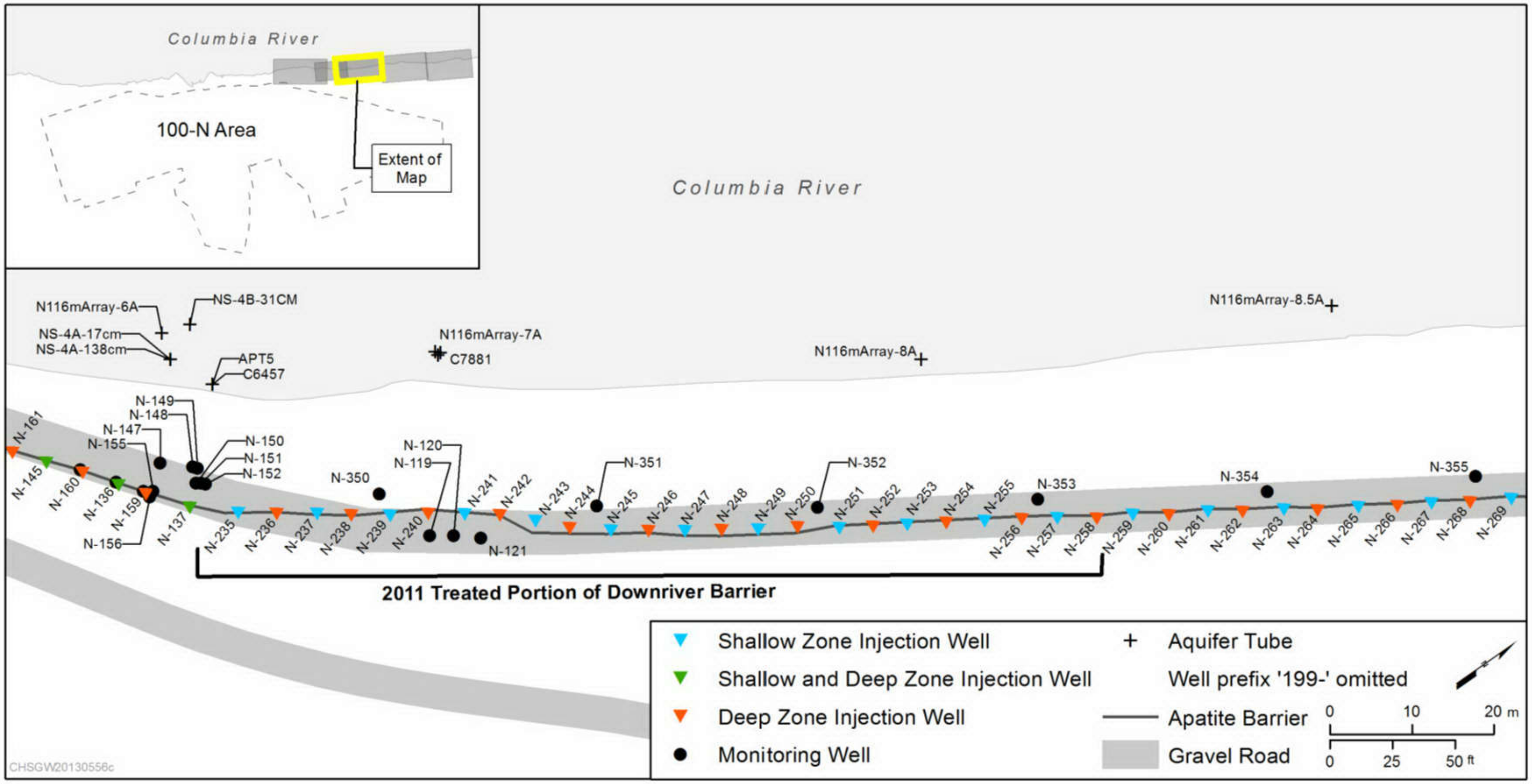
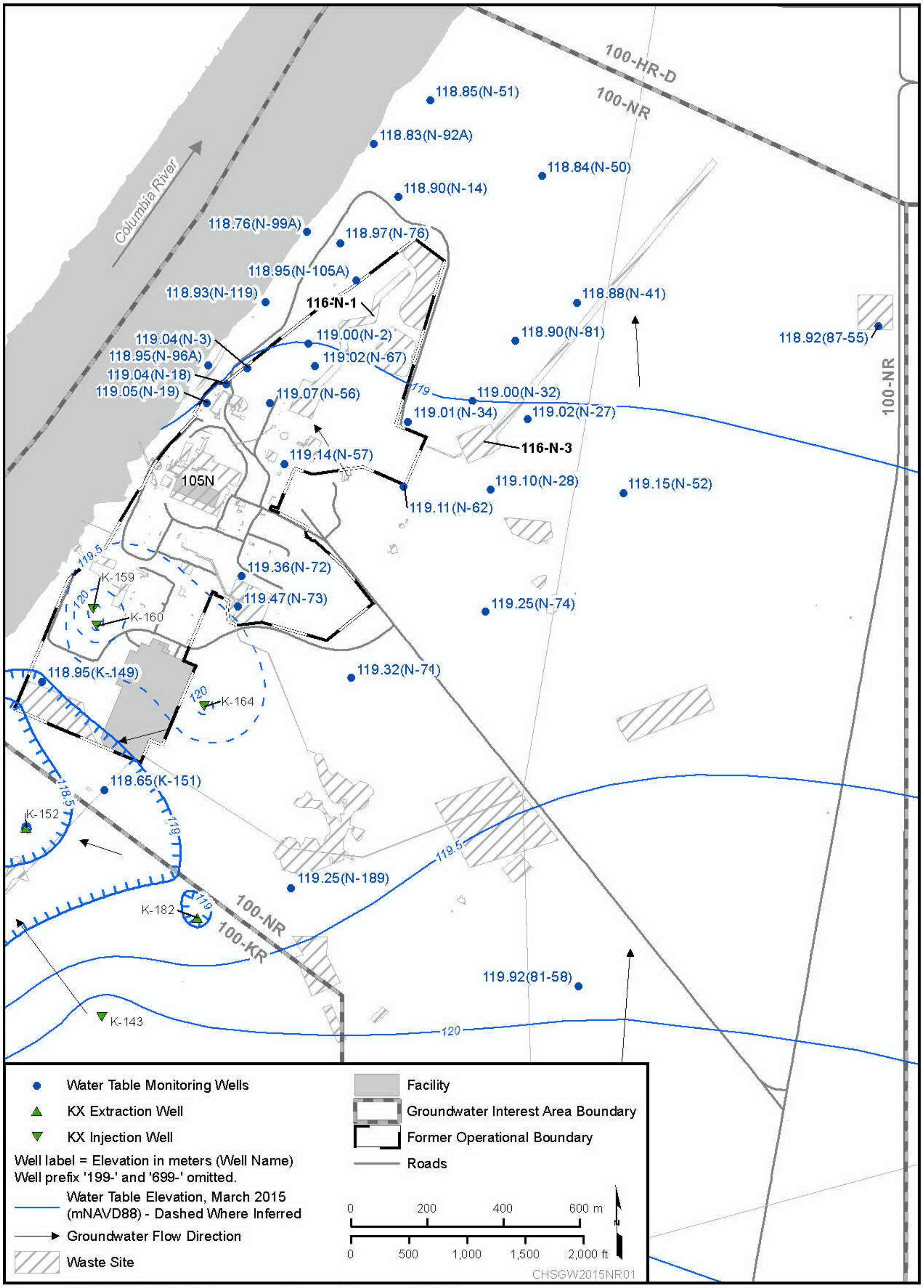


Figure 4-5. Downriver Extension Apatite Barrier Monitoring Wells and Aquifer Tubes along the Columbia River Shoreline



Source: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-6. 100-N Area Water Table Map, March 2015

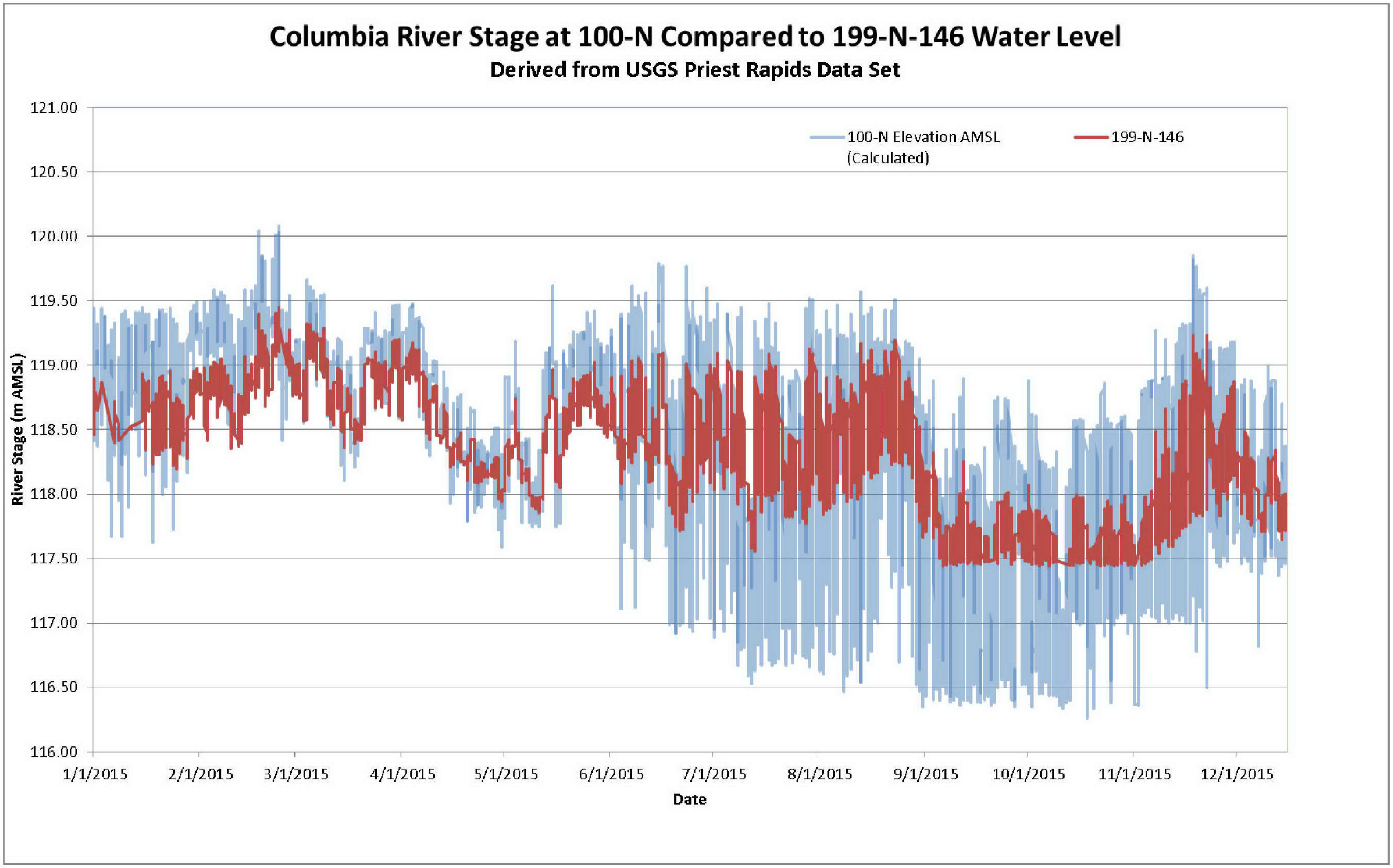
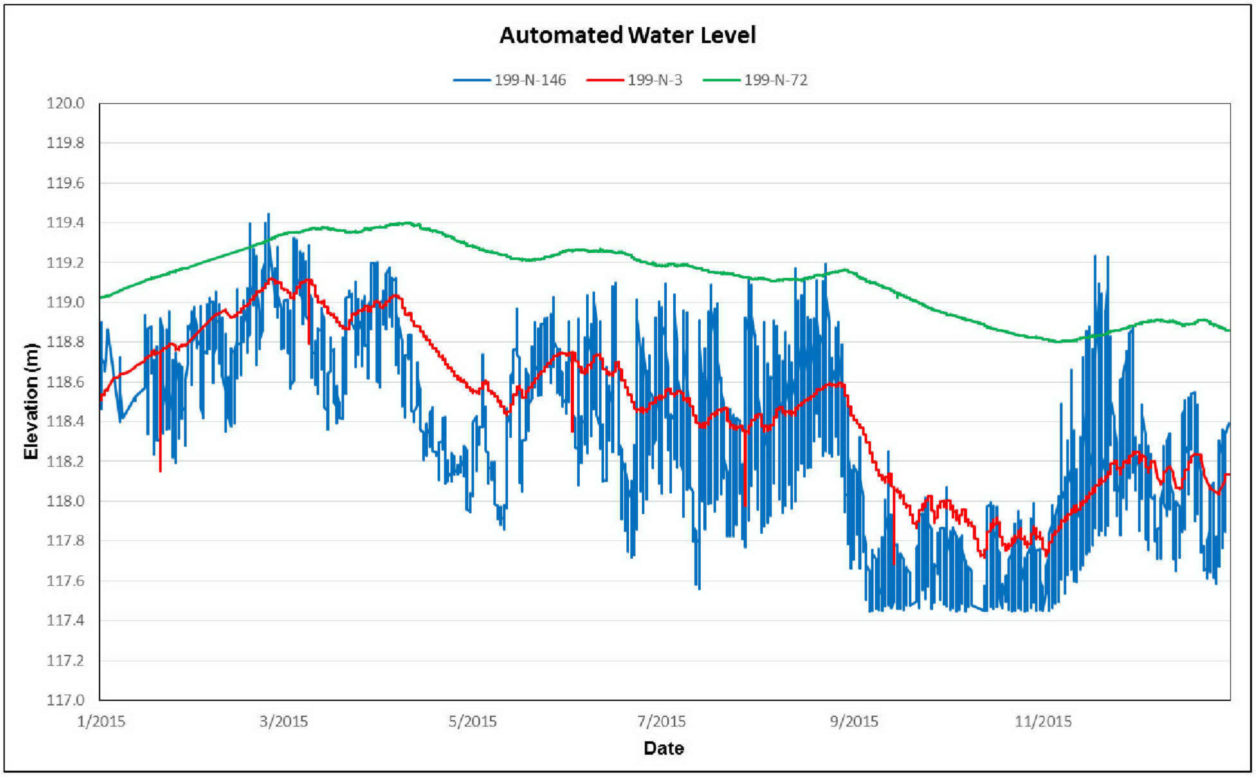
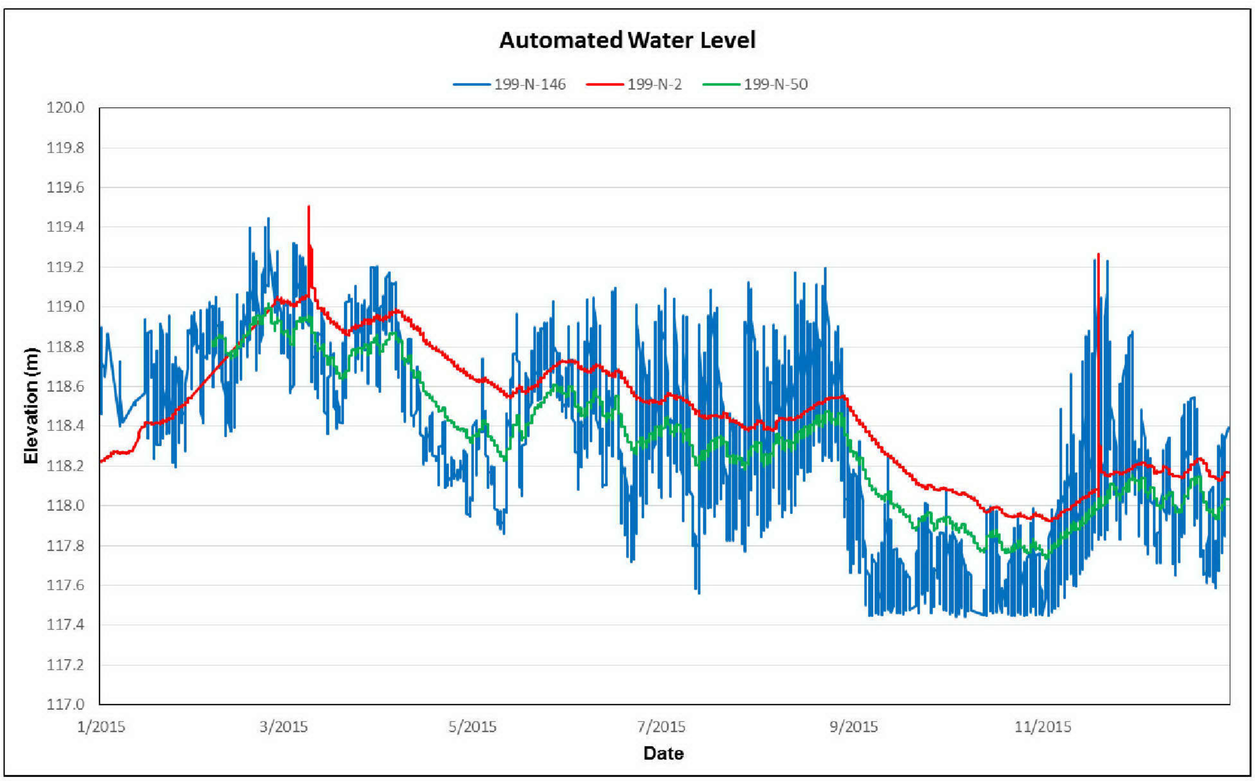


Figure 4-7. Well 199-N-146 Water Level Compared to Elevation of the Columbia River at the 100-N Area, 2015

1 

2 **Figure 4-8. Daily Average Water Level in Wells 199-N-146, 199-N-3, and 199-N-72, 2015**

3 

4 **Figure 4-9. Daily Average Water Level in Wells 199-N-146, 199-N-2, and 199-N-50, 2015**

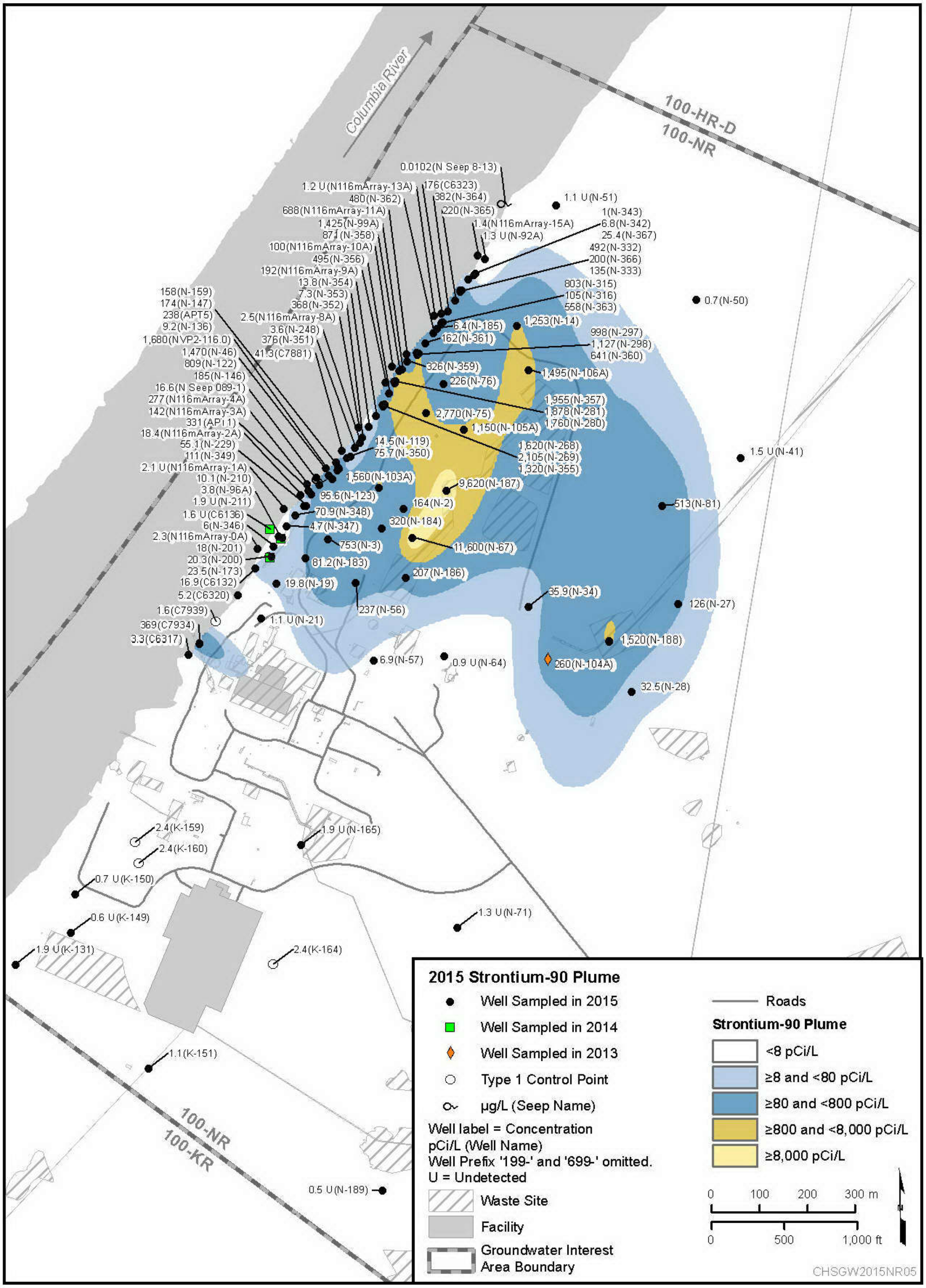


Figure 4-10. Strontium-90 Plume Map for the 100-N Area, 2015

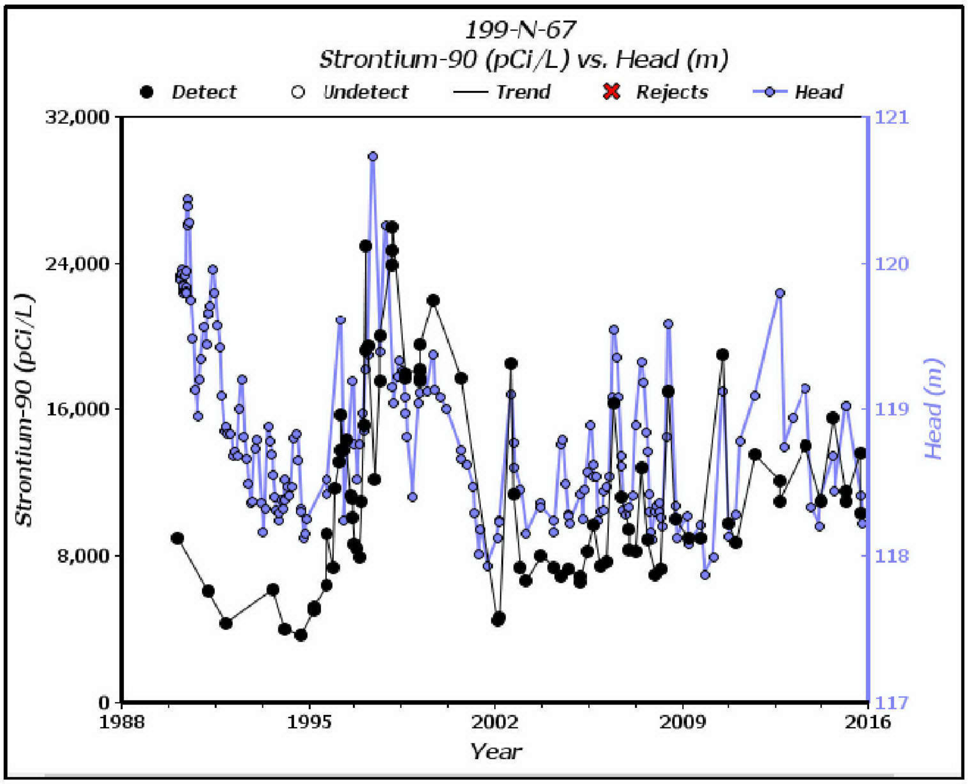
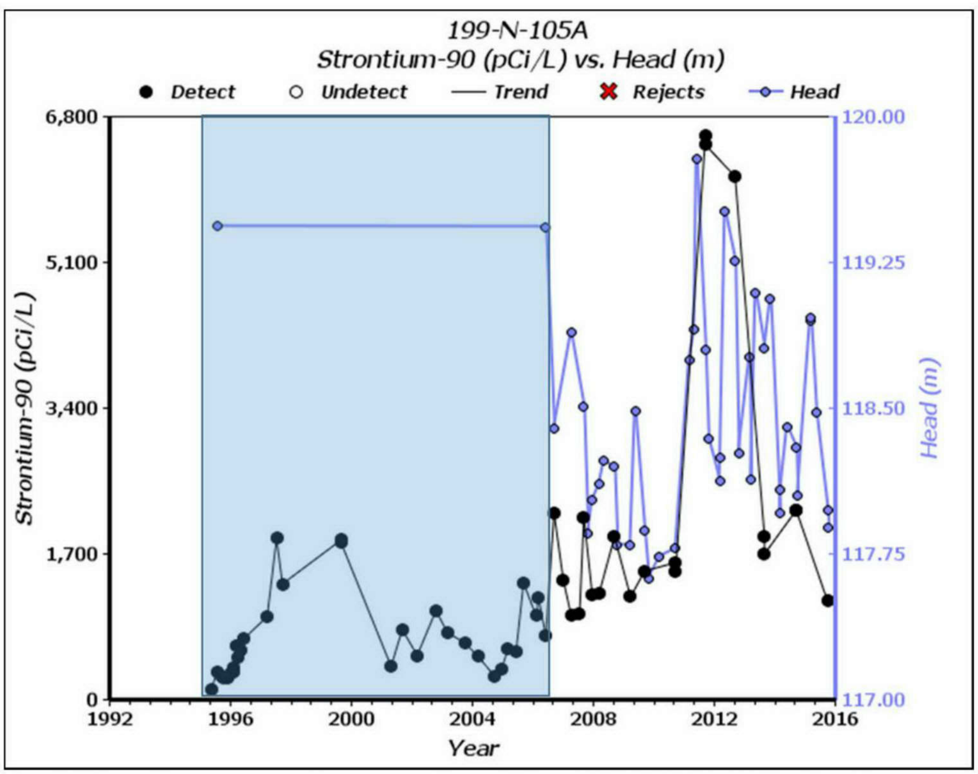


Figure 4-11. Strontium-90 Trend Plot and Water Levels for Well 199-N-67



Note: Well was former pump and treat extraction well from 1995-2006 (shaded band area).

Figure 4-12. Strontium-90 Trend Plot and Water Levels for Well 199-N-105A

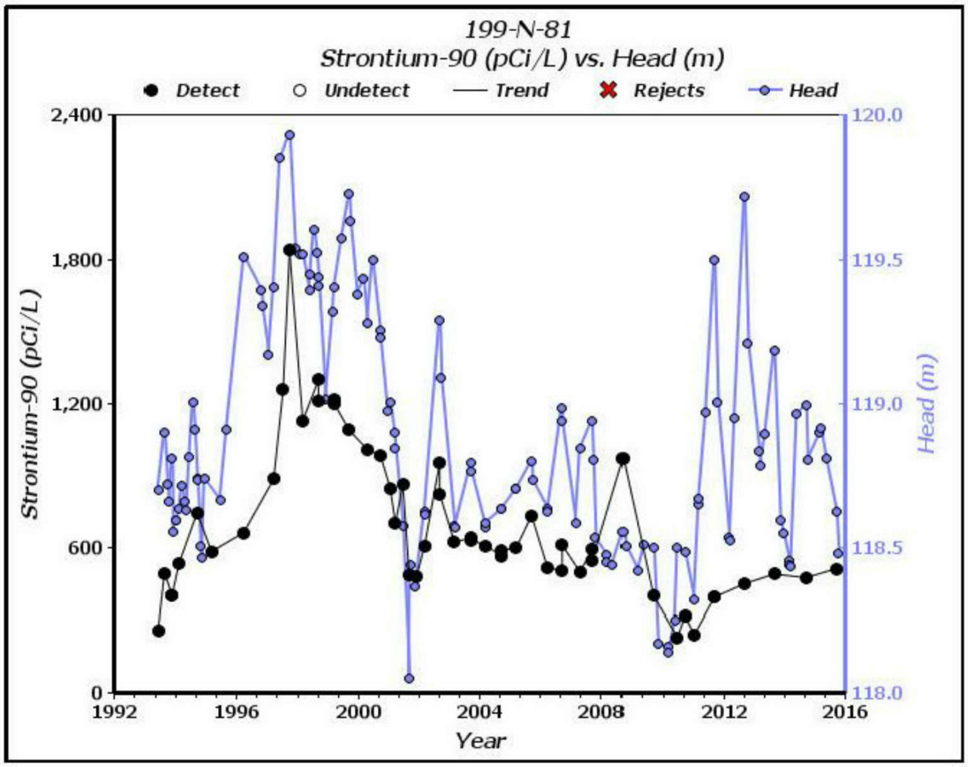


Figure 4-13. Strontium-90 Trend Plot and Water Levels for Well 199-N-81

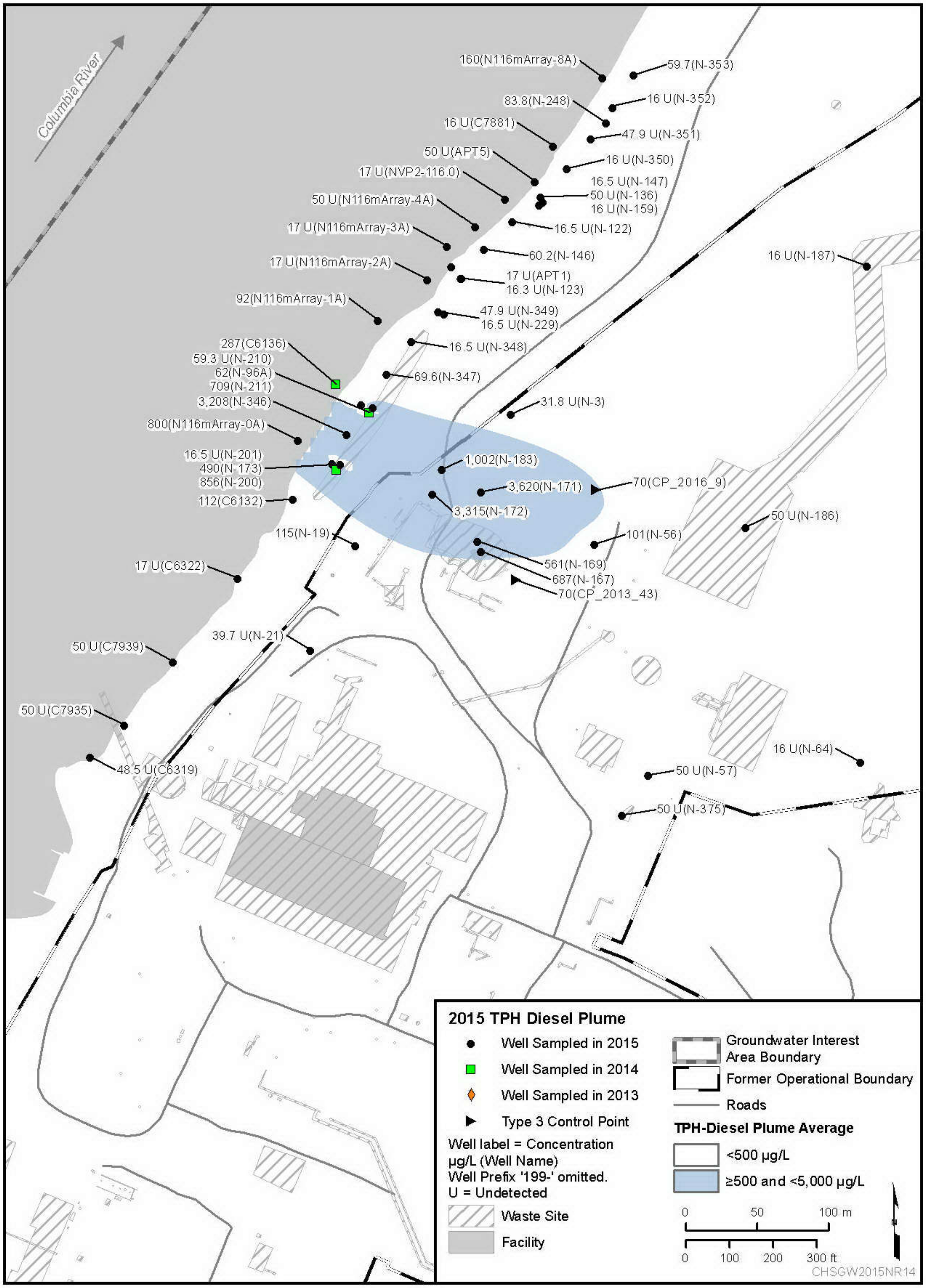


Figure 4-14. TPH-Diesel Plume Map for the 100-N Area, 2015

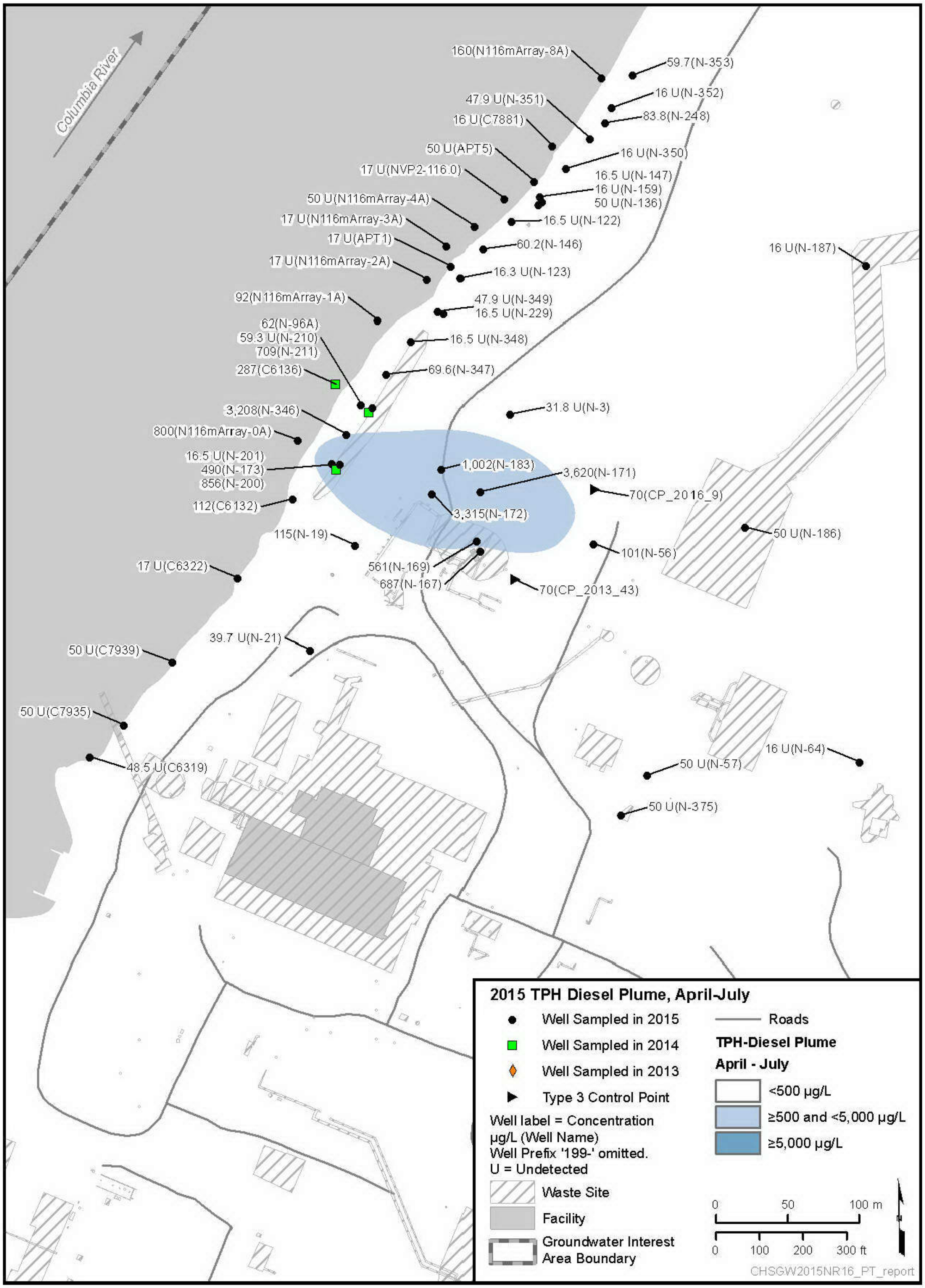


Figure 4-15. TPH-Diesel and TPH Motor Oil Plume Map, July 2015

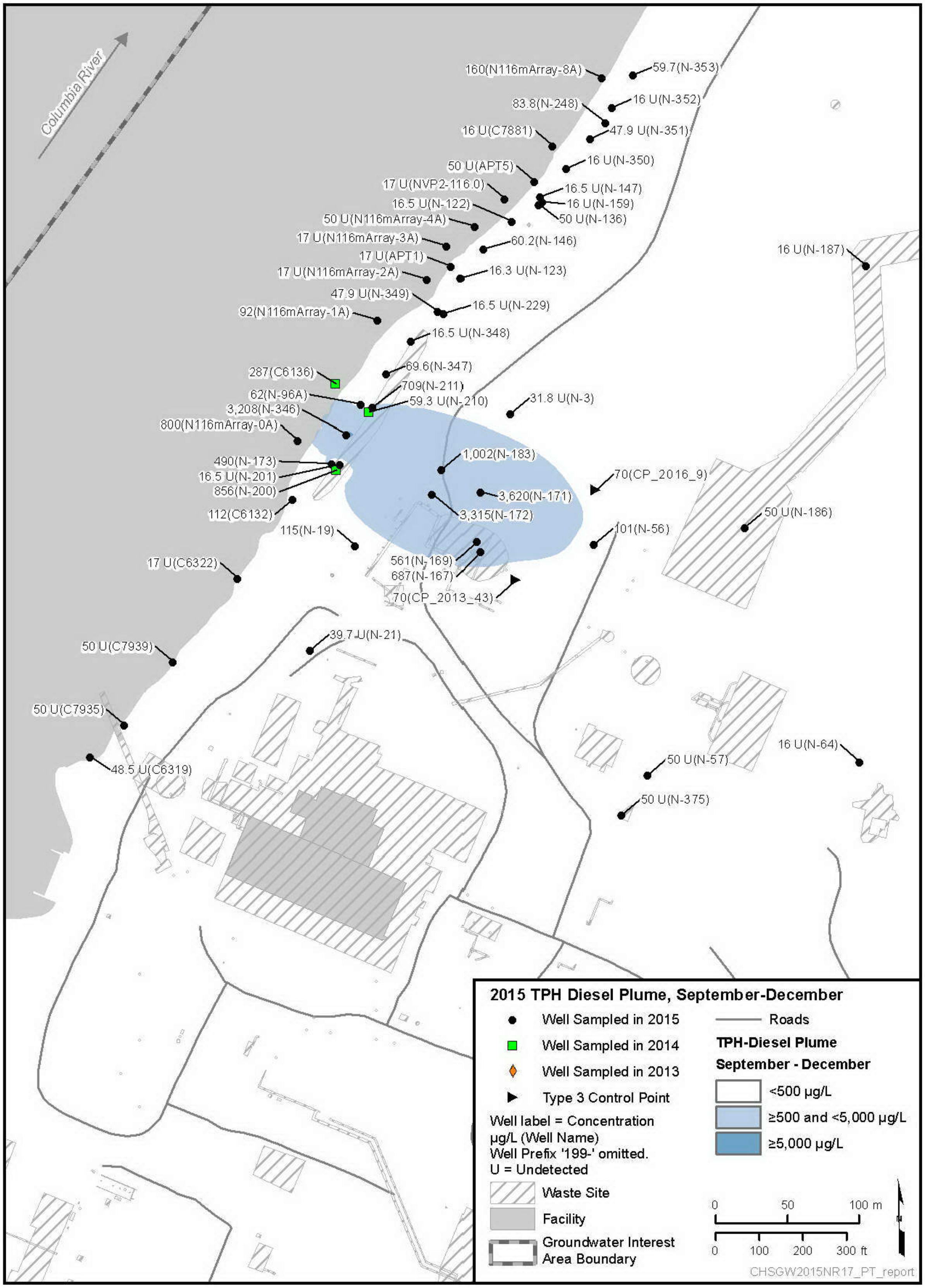
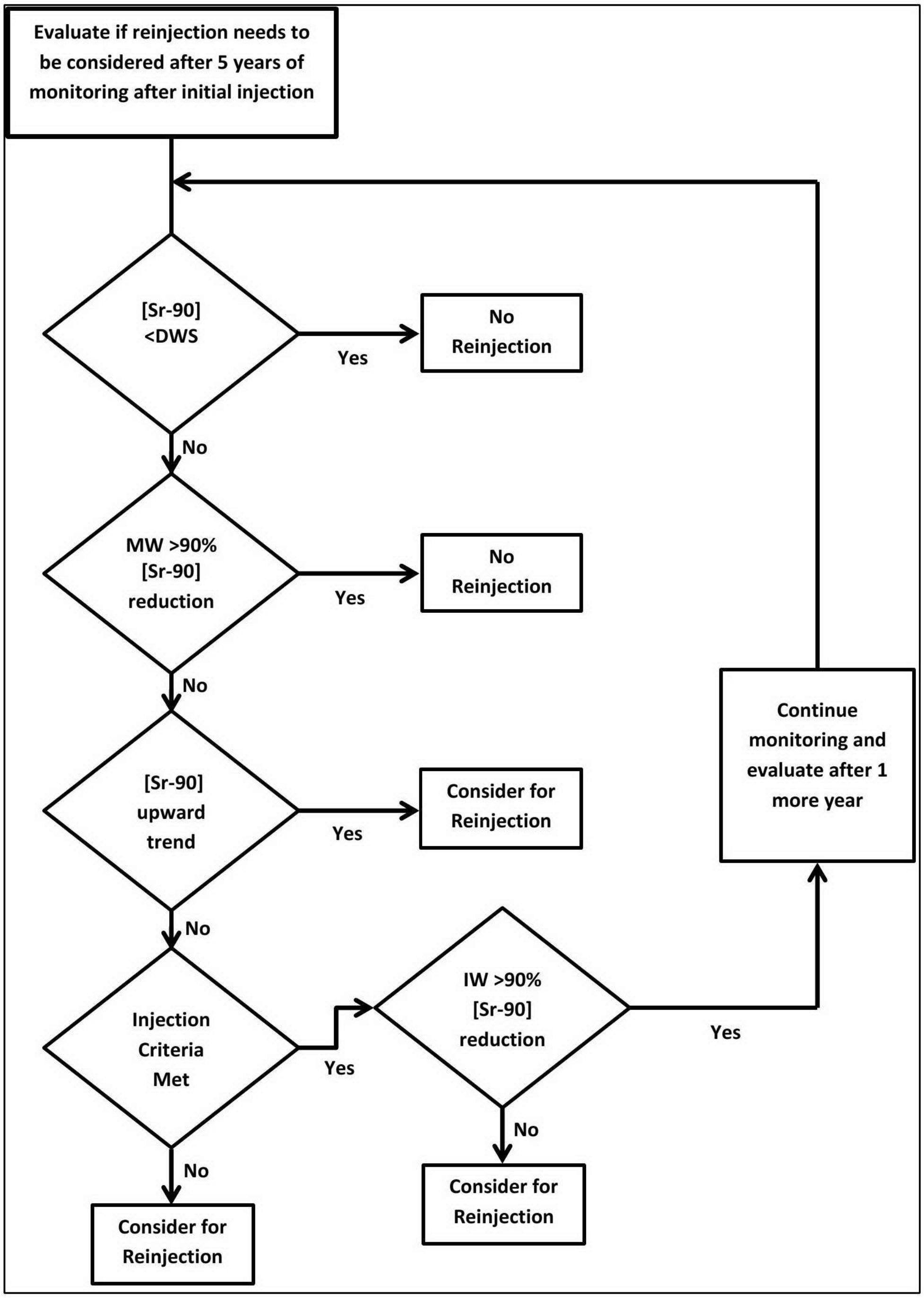


Figure 4-16. TPH-Diesel and TPH Motor Oil Plume Map, December 2015



DWS = drinking water standard; IW = injection well; MW = monitoring well

Figure 4-17. Reinjection Decision Flow Diagram

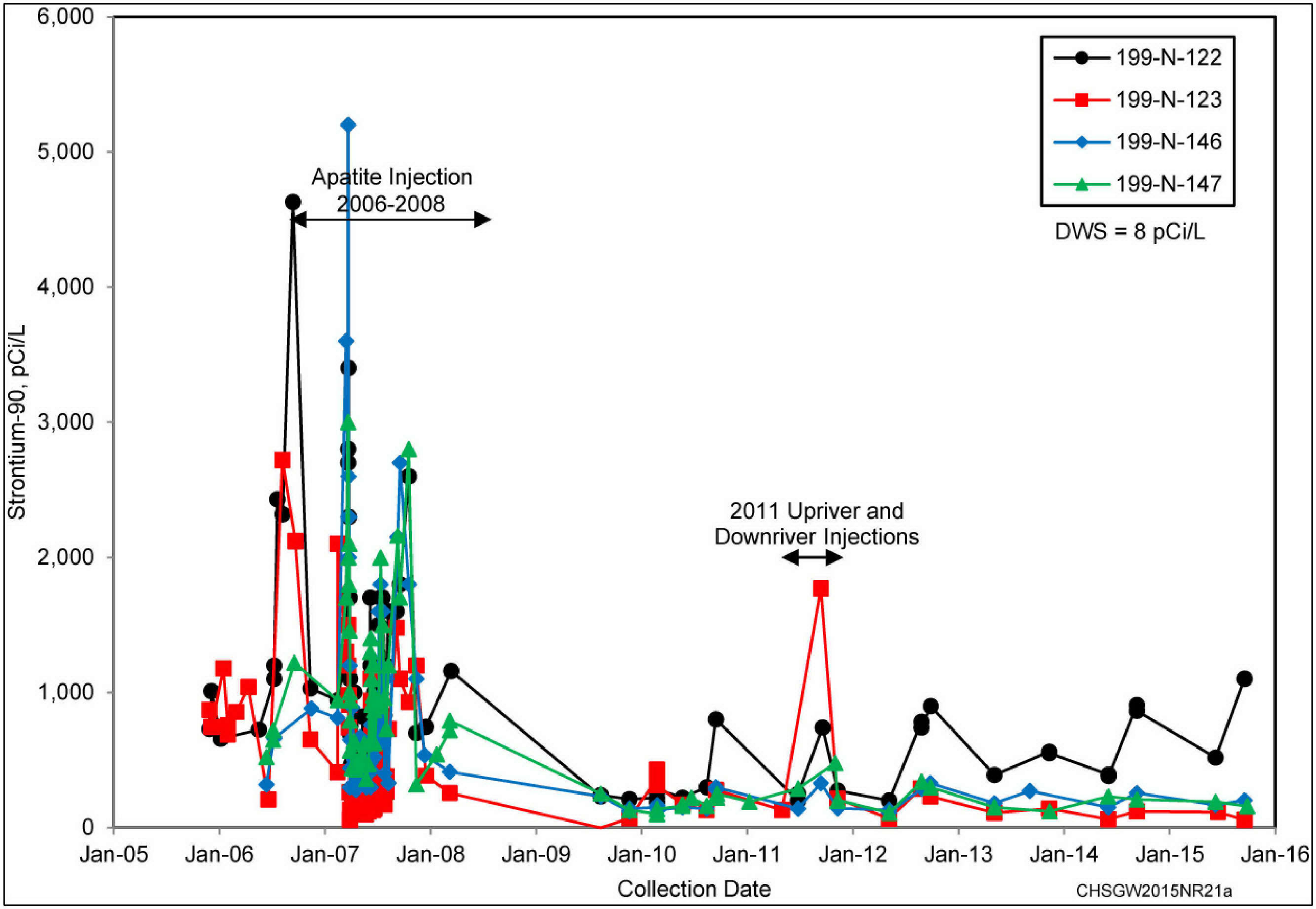


Figure 4-18. Strontium-90 Data for Performance Monitoring Wells along the Central Segment of the Apatite PRB

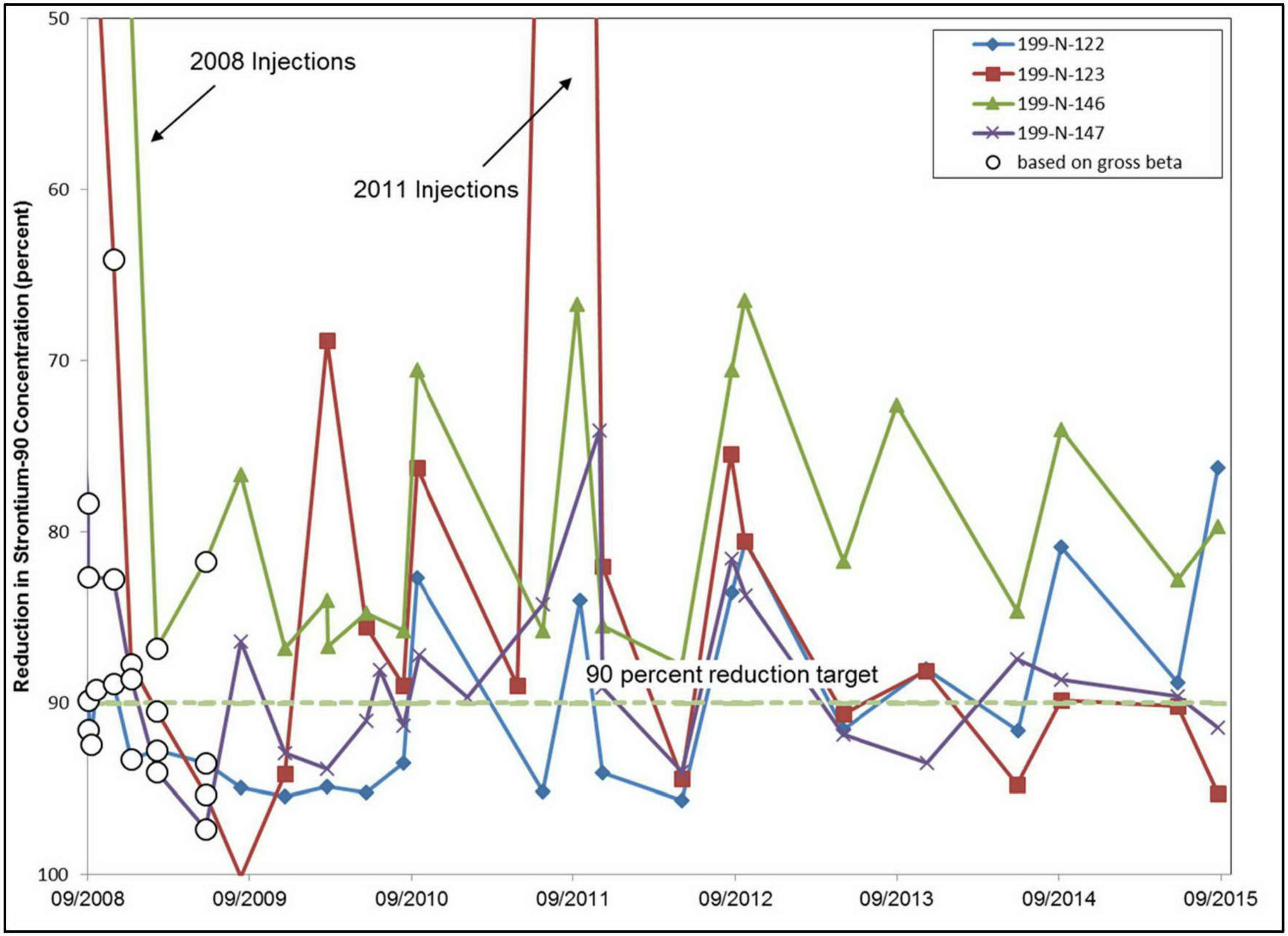


Figure 4-19. Original Apatite Performance Monitoring Wells Percent Strontium-90 Reductions, 2015

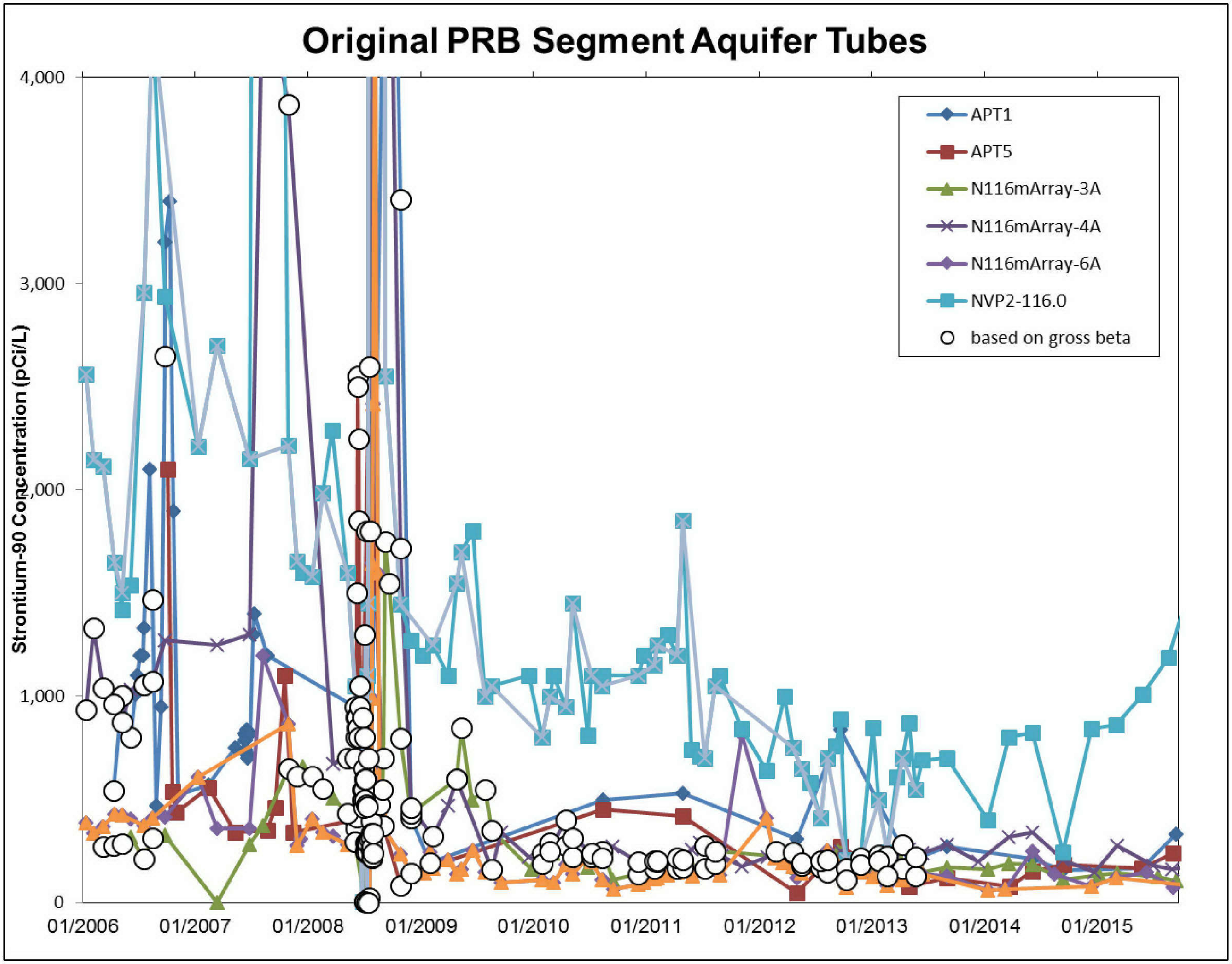


Figure 4-20. Strontium-90 Data for Aquifer Tubes along the Central Segment of the Apatite PRB

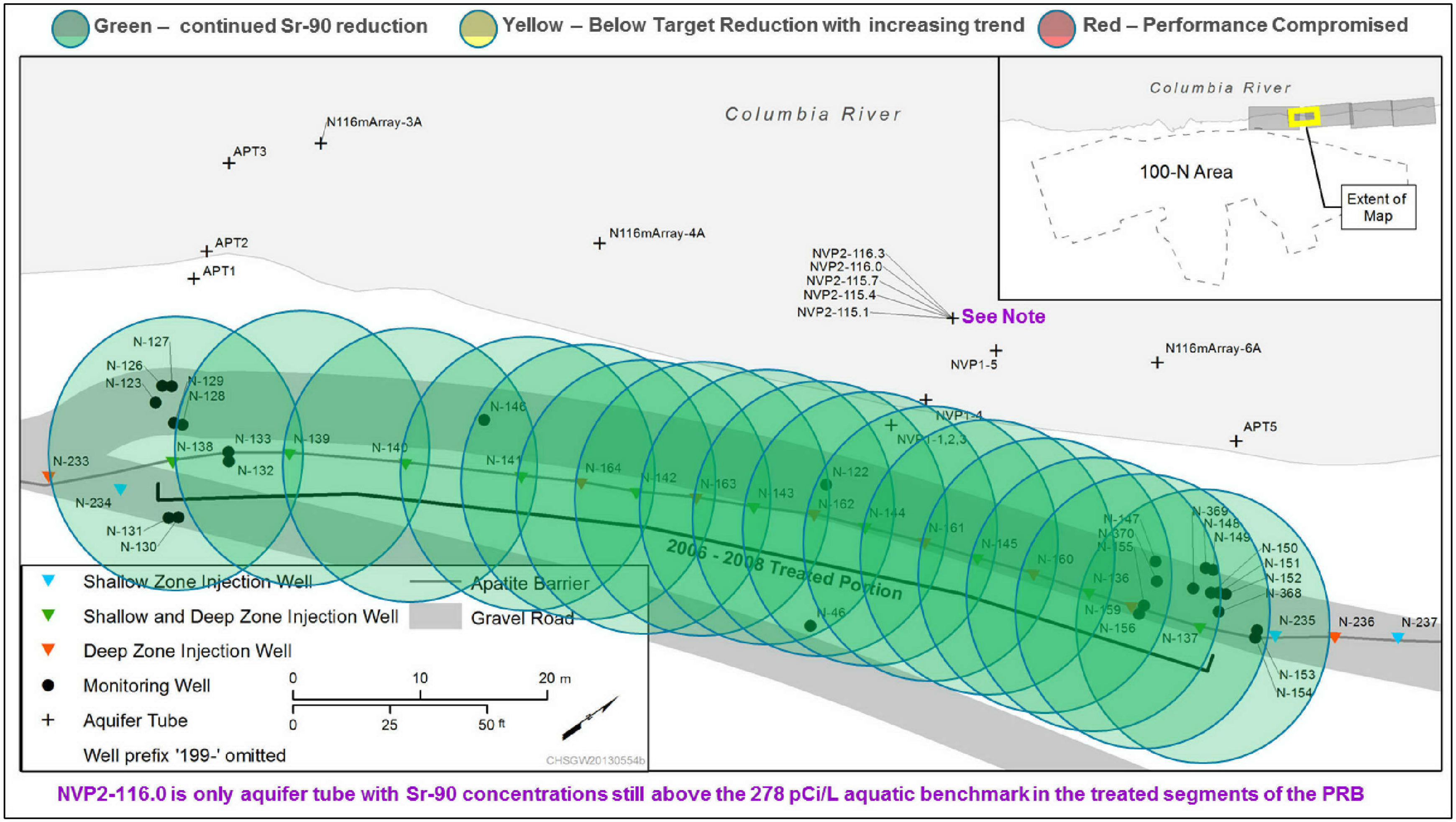


Figure 4-21. Original PRB Segment Performance Assessment for 2015

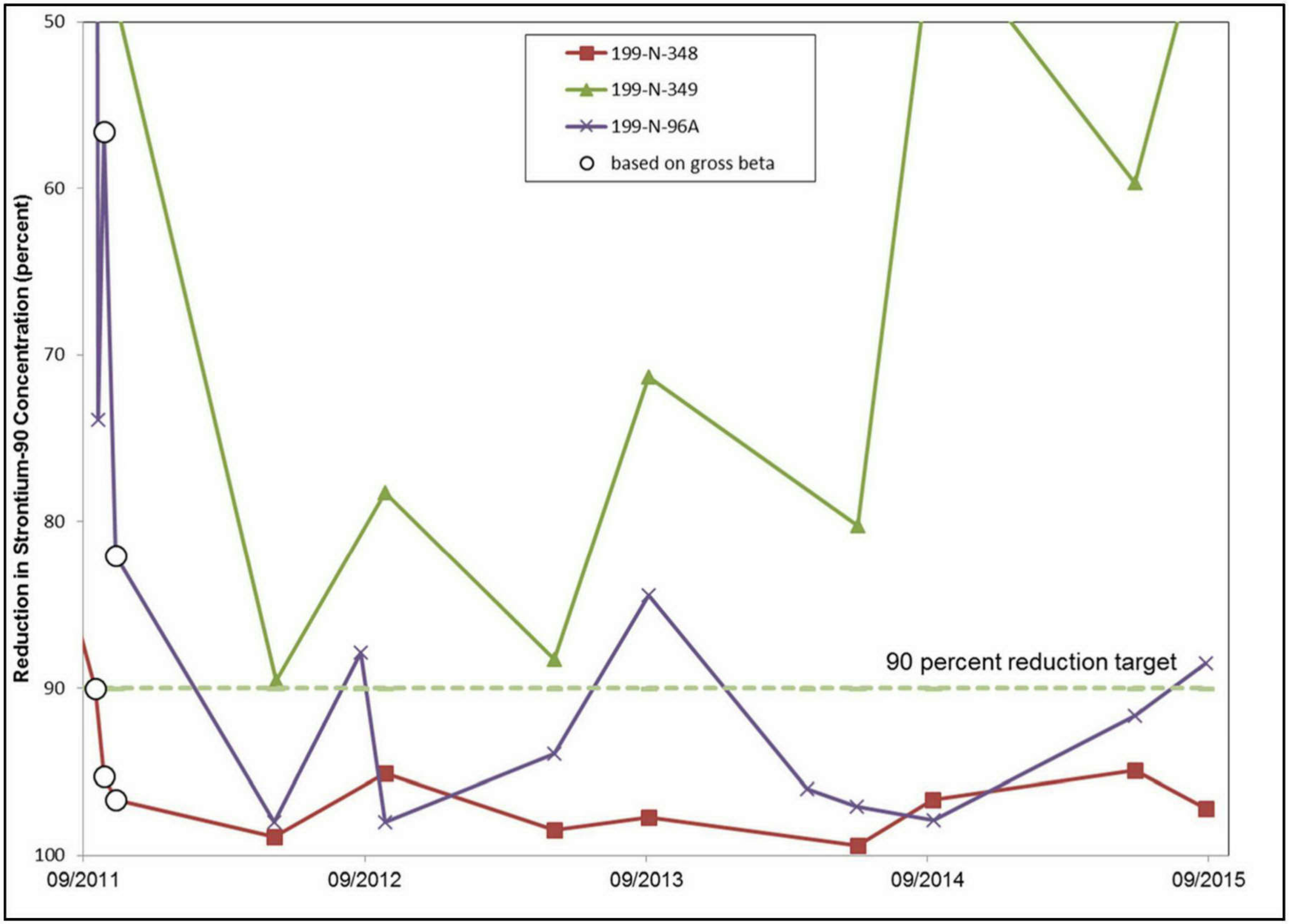


Figure 4-22. Upriver Apatite Barrier Extension Performance Monitoring Wells Percent Strontium-90 Reductions, 2015

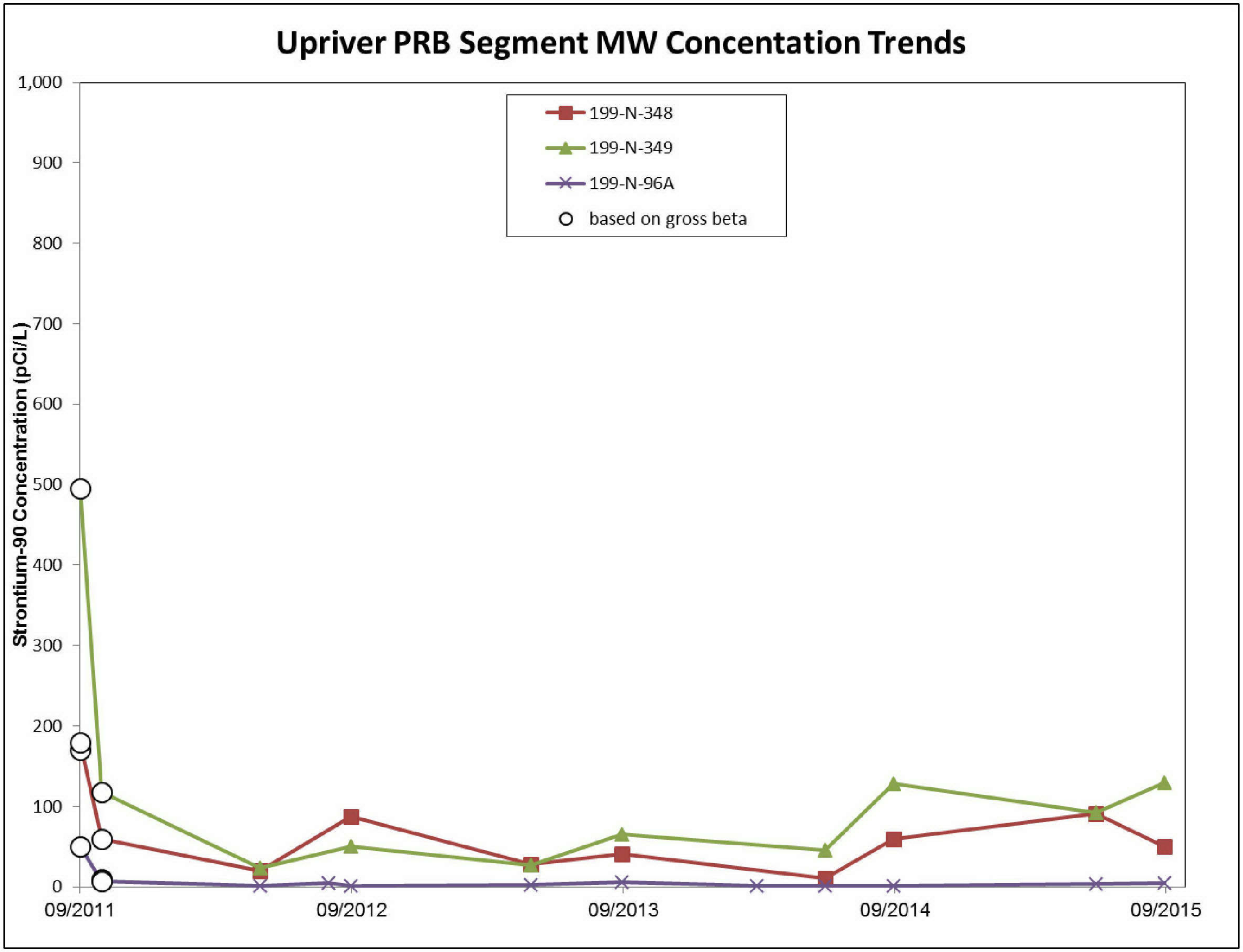


Figure 4-23. Strontium-90 Data for Performance Monitoring Wells along the Upriver Segment of the Apatite PRB

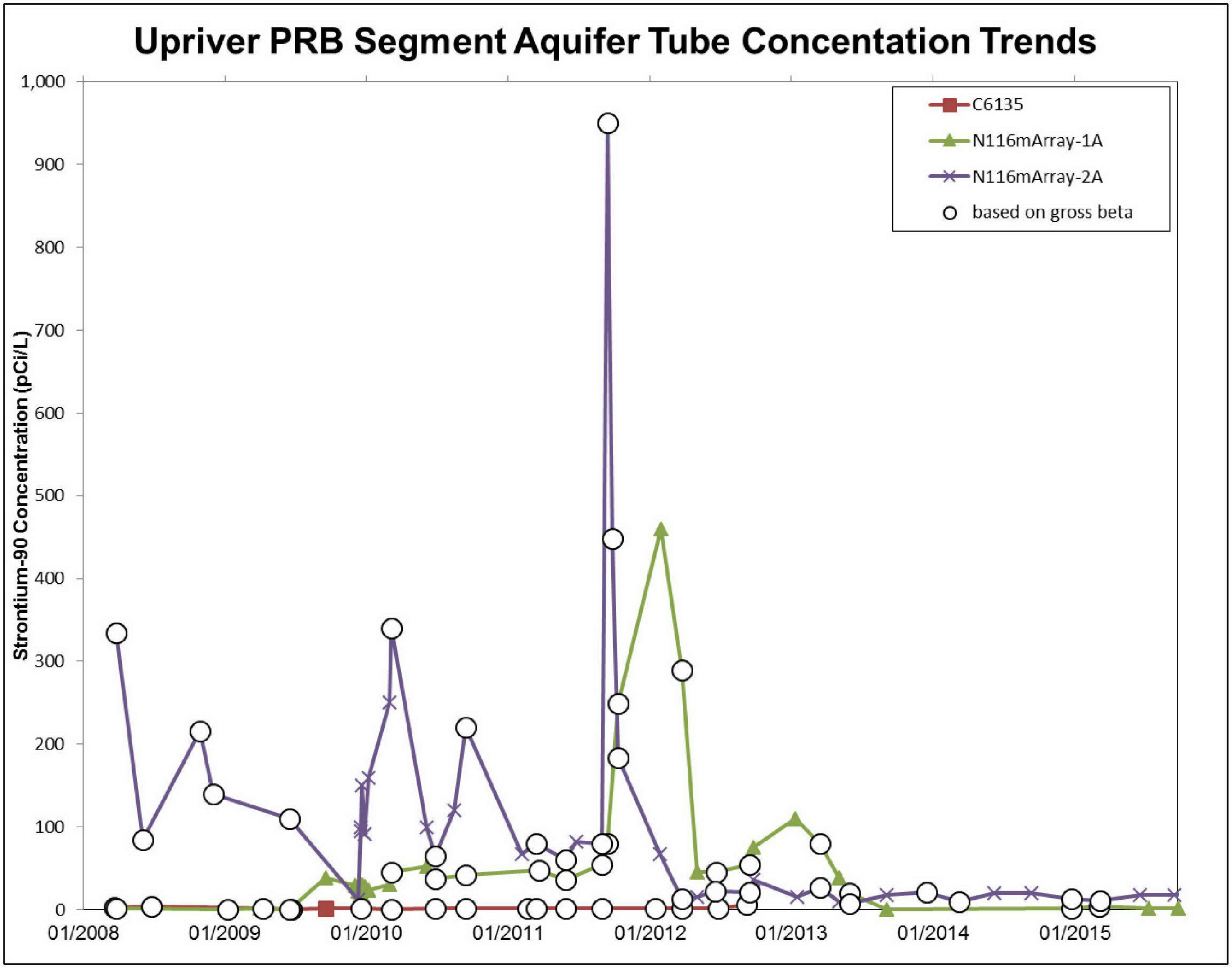


Figure 4-24. Strontium-90 Data for Aquifer Tubes along the Upriver Segment of the Apatite PRB

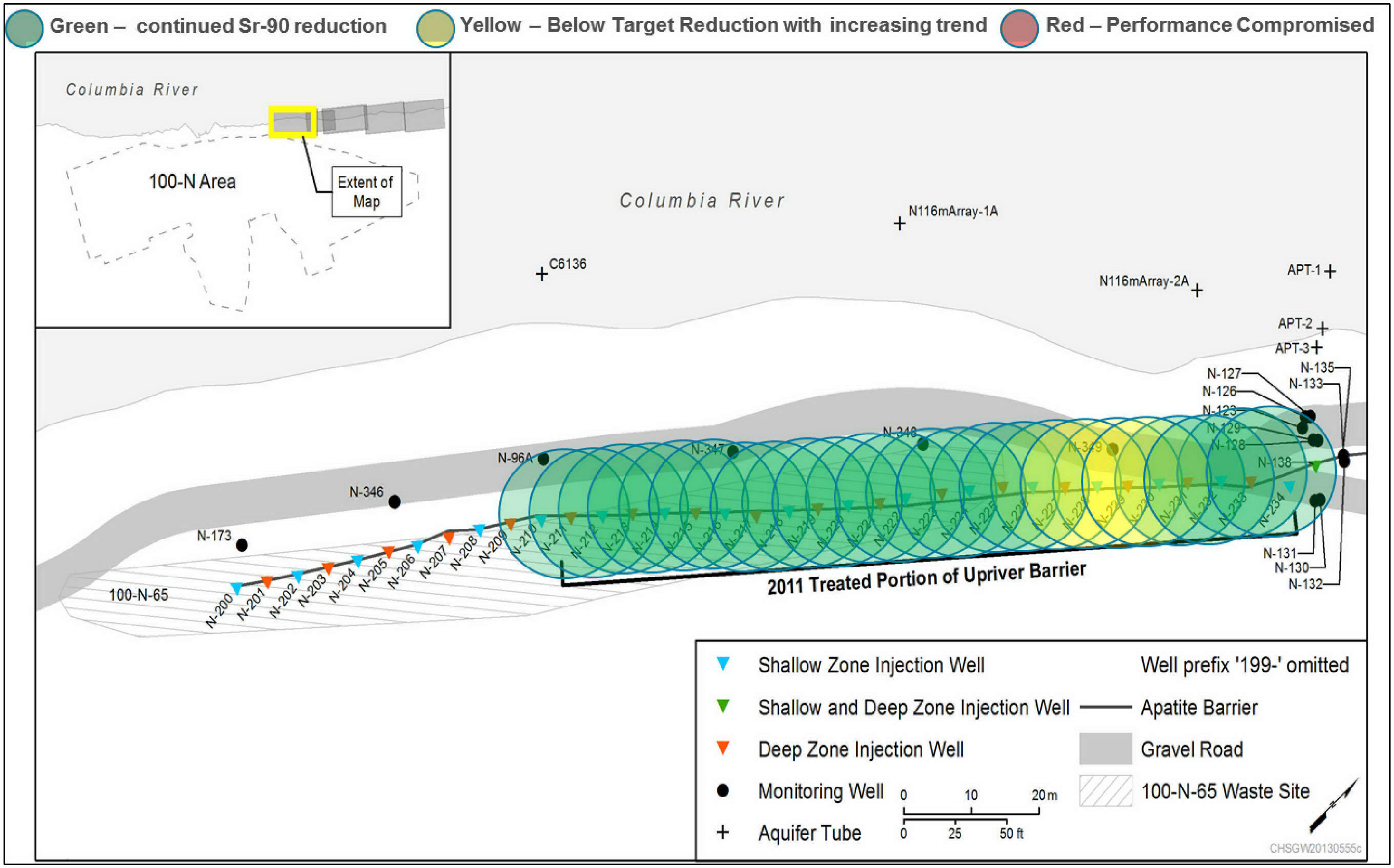


Figure 4-25. Upriver PRB Segment Performance Assessment for 2015

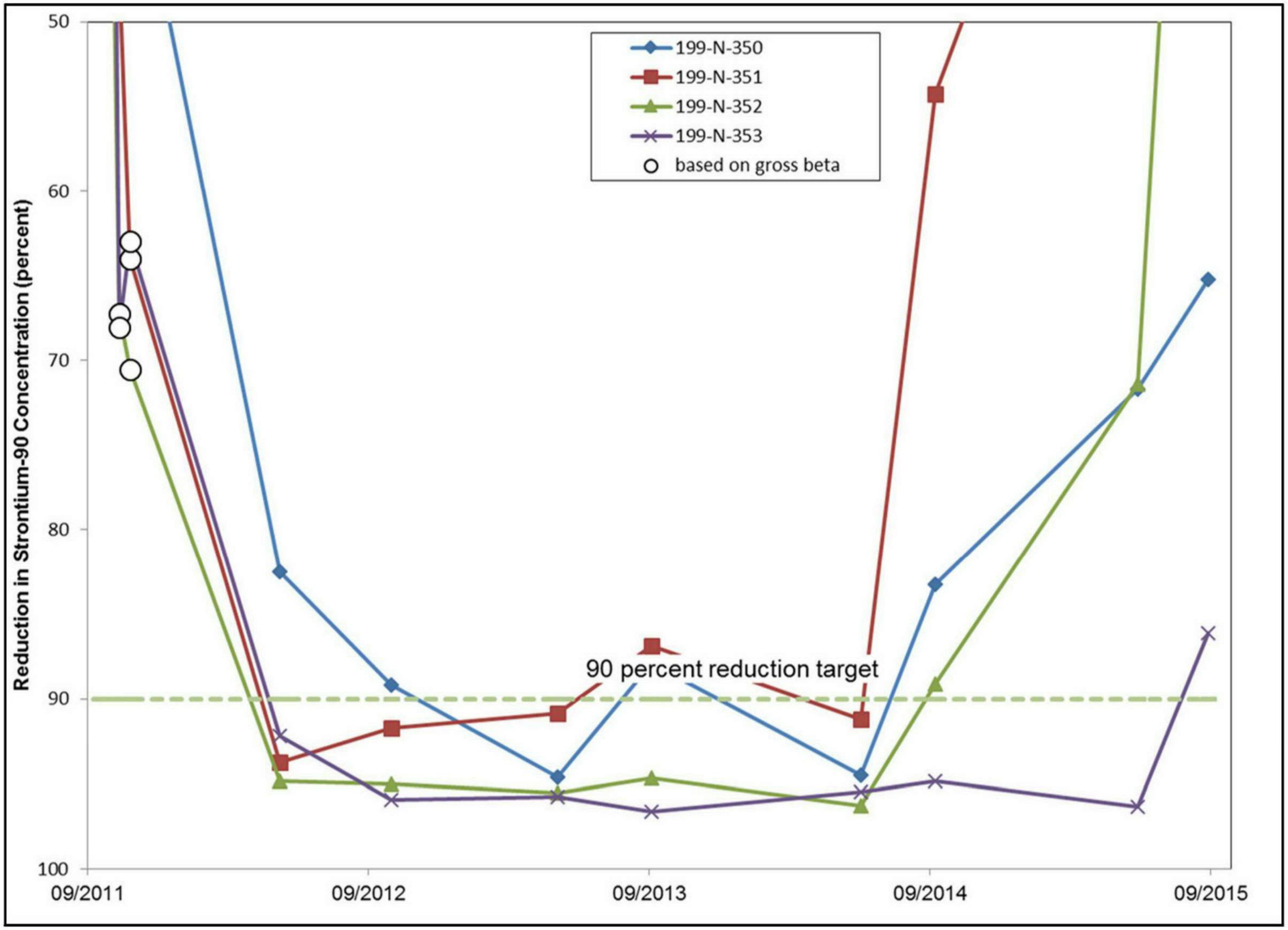


Figure 4-26. Downriver Apatite Barrier Extension Performance Monitoring Wells Percent Strontium-90 Reductions, 2015

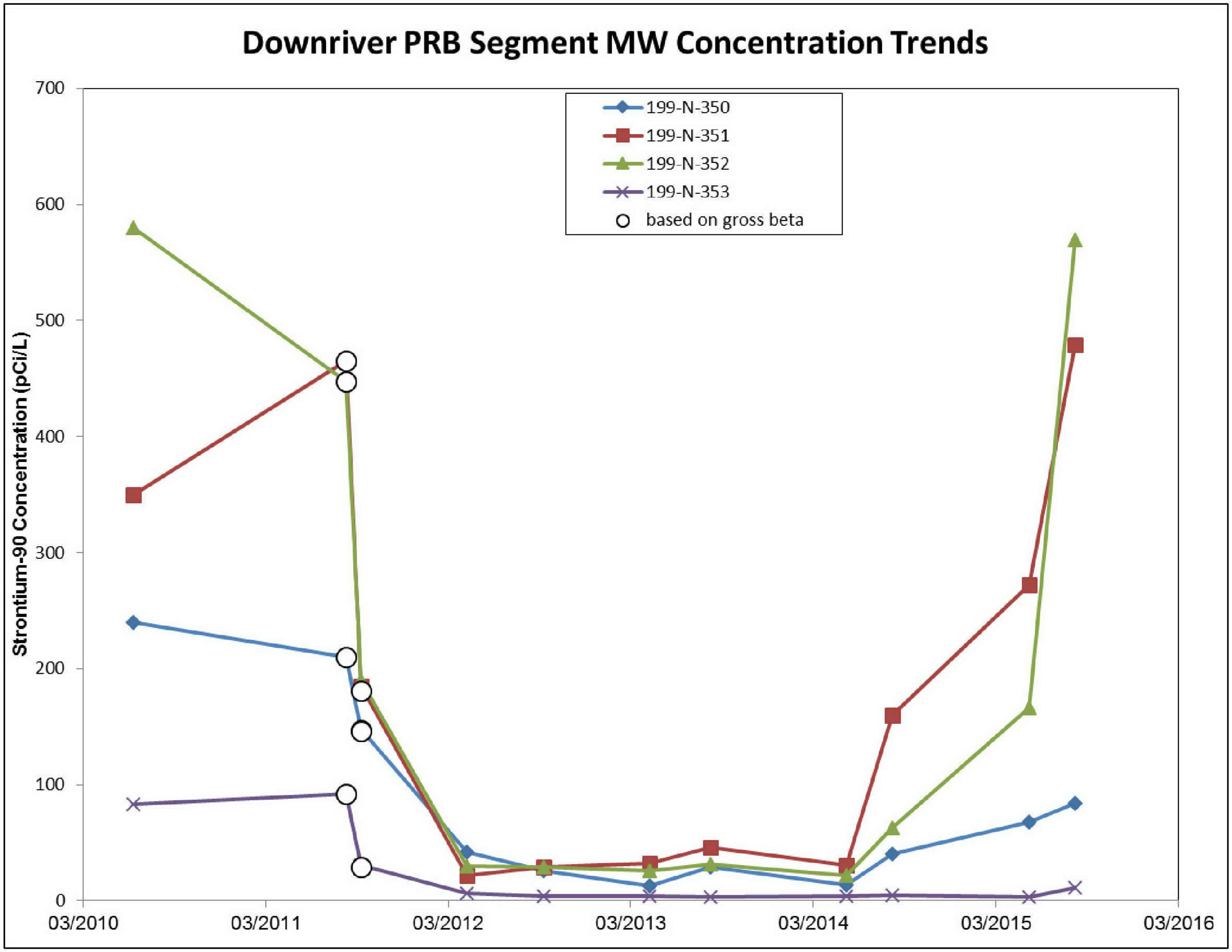


Figure 4-27. Strontium-90 Data for Performance Monitoring Wells along the Downriver Segment of the Apatite PRB

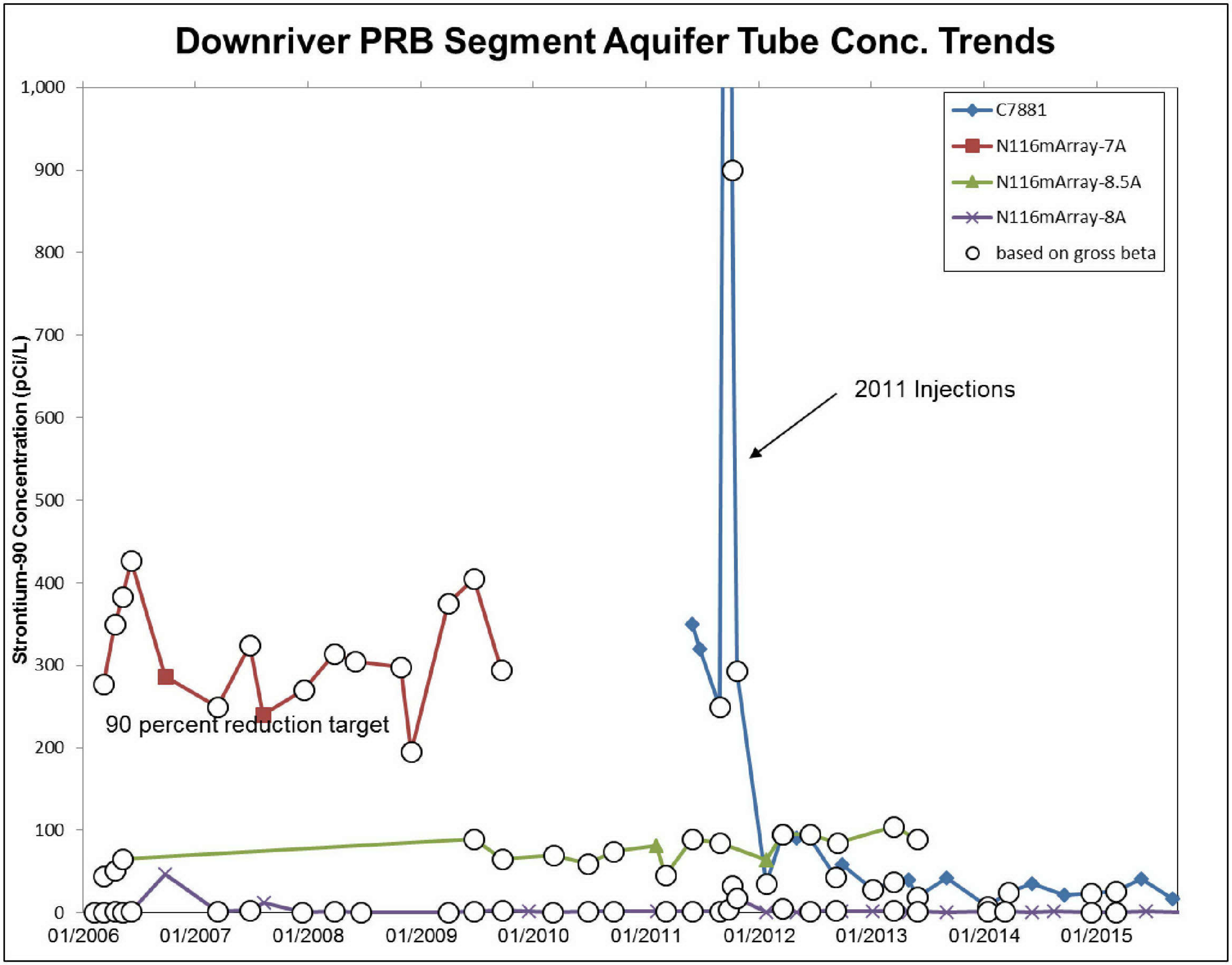


Figure 4-28. Strontium-90 Data for Aquifer Tubes along the Downriver Segment of the Apatite PRB

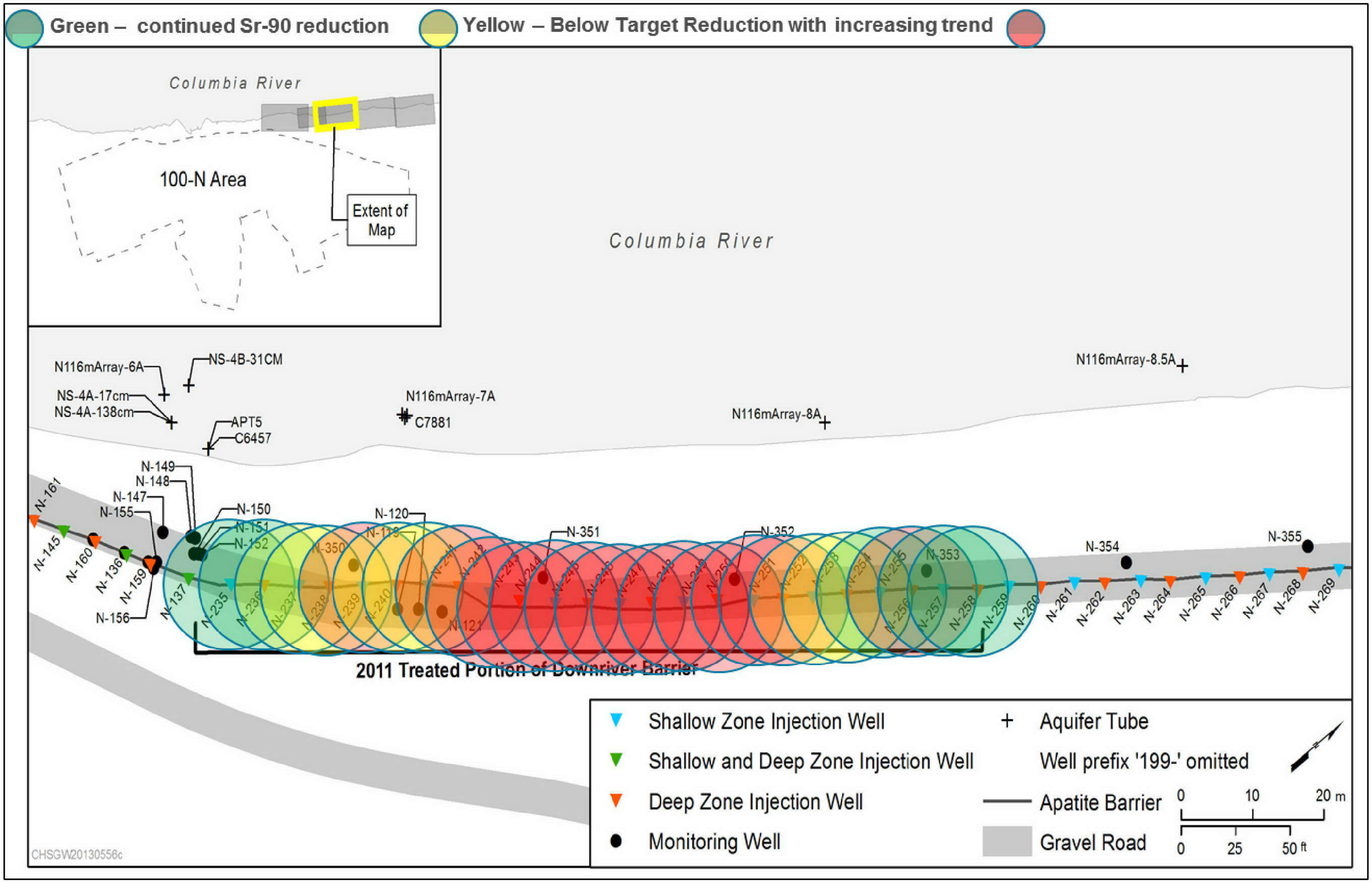


Figure 4-29. Downriver PRB Segment Performance Assessment for 2015

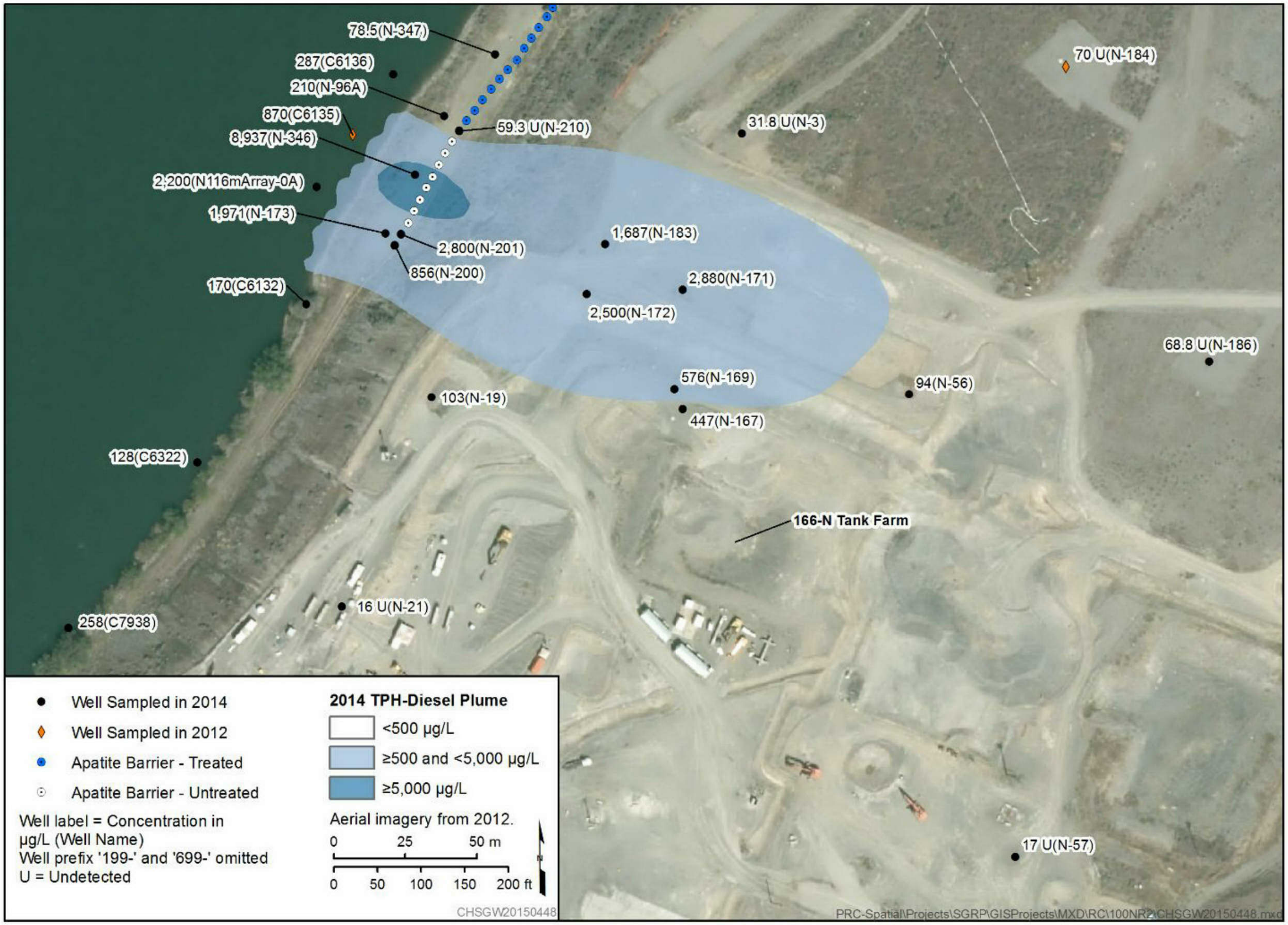


Figure 4-30. 166-N Tank Farm Facility, Location of Well 199-N-183 and 2014 TPH Groundwater Plume

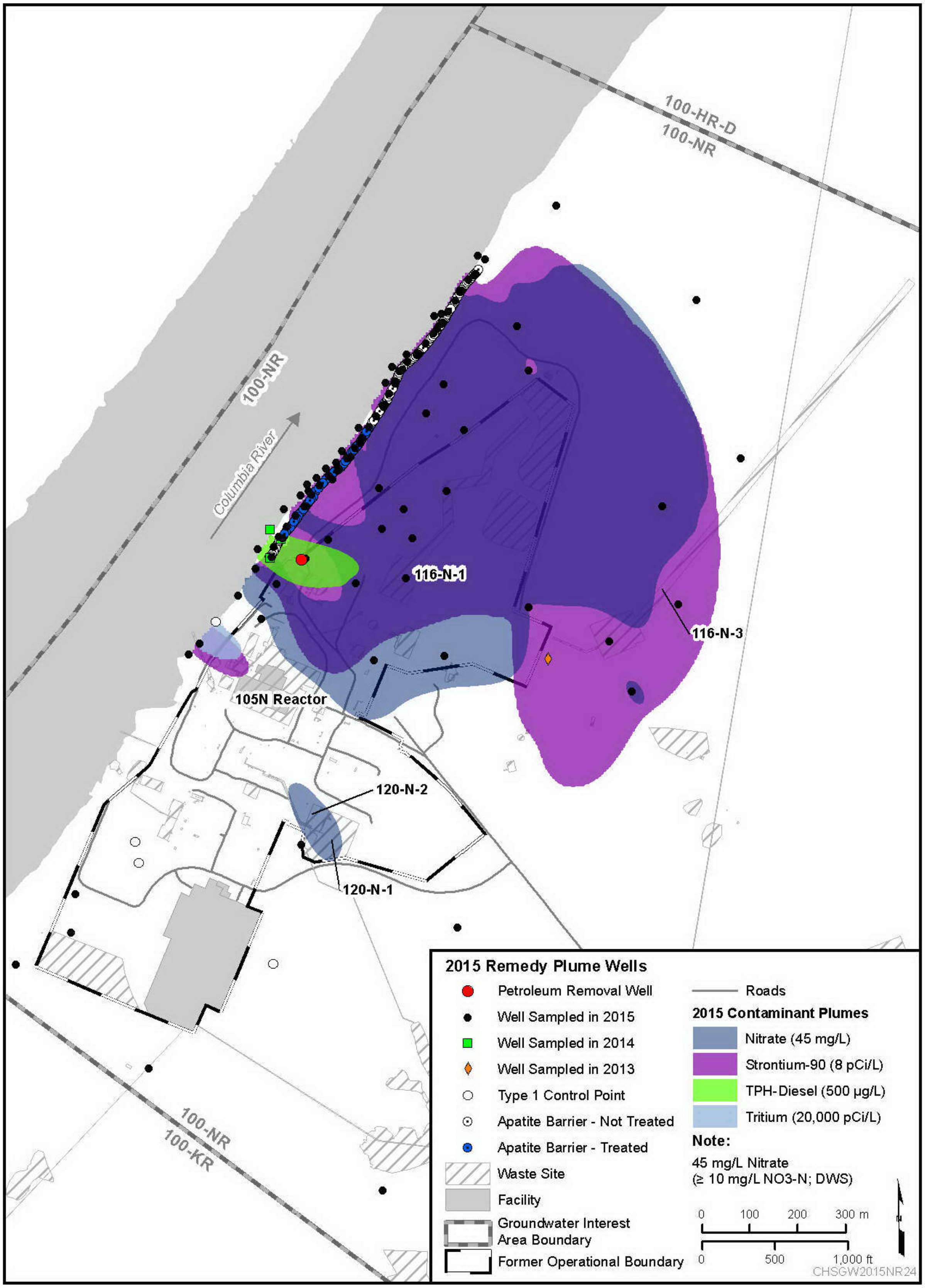


Figure 4-31. 100-NR Contaminant Plumes, 2015

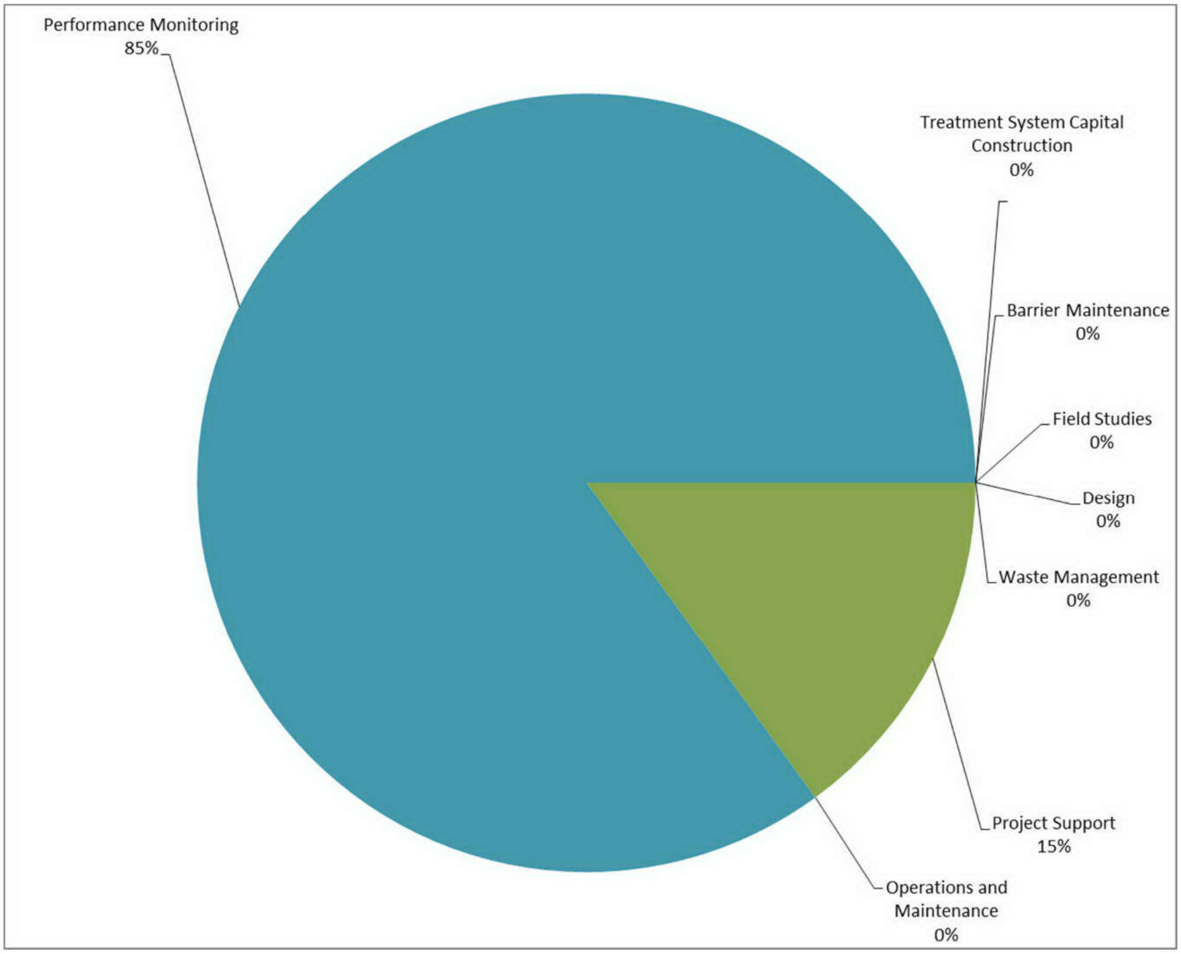


Figure 4-32. 100-NR-2 Apatite Barrier 2015 Cost Breakdown (by Percentage)

Table 4-1. Well Water-Level Response to Changes in River Stage

199-N-146		199-N-3		199-N-72	
Date	**Average Elevation[a] (m)**	**Date**	**Average Elevation[a] (m)**	**Date**	**Average Elevation[a] (m)**
Late Winter Low[b]					
3/19/2015	118.44	3/21/2015	118.87	3/26/2015	119.36
Early Summer High					
5/27/2015	118.88	5/30/2015	118.75	6/4/2015	119.26
Late Fall/Early Winter Low					
10/13/2015	117.53	10/20/2015	117.77	11/7/2016	118.80

a. Based on hourly water-level elevation data.

b. River levels unusually high in March 2015 and were highest in late winter/early spring for 2015. Normally observed high in May through July did not occur in 2015 because of low snow pack in the Cascade Mountains

Table 4-2. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/ Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	2015 (pCi/L)	Percent Change, 1994 to 2015	Percent Change 2005 to 2015
Monitoring Wells												
199-N-2	121	80.7	1,100	160	NS	NS	3,300	1,040	777	164	36	103
199-N-3	927	1,330	1,200	1,060	870	1,200	1,300	960	938	859	-7	-35
199-N-14	1,210	1,070	1,300	1,360	1,400	1,730	960	1,200	1,120	1,380	14	29
199-N-16	0.34	-0.08 (U)	0.06 (U)	-0.04 (U)	-2.70 (U)	-0.12 (U)	0.11 (U)	Decom. 12/18/2012	Decom. 12/18/2012	Decom. 12/18/2012	NC	NC
199-N-18	392	NS	290	-12 (U)	260	203	In use for TPH-diesel remediation	In use for TPH-diesel remediation	In use for TPH-diesel remediation	In use for TPH-diesel remediation	NC	NC
199-N-19	43.6	28.2	NS	NS	23	26.4	23	22	23[a]	17.1	-61	-39
199-N-21	1.50	NS	NS	-2.60 (U)	-7.6 (U)	1.22	1.2	1.8	0.31 (U)	-0.193 (U)	NC	NC
199-N-27	171	167	160	130	125	194	200	130	129	126	-26	-25
199-N-28	120	25.1	21	25	20	34.9	35	24	33	32.5	-73	29
199-N-32	1.27	0.358 (U)	-1.40 (U)	-1.60 (U)	-4.8 (U)	0.15 (U)	0.36 (U)	0.77 (U)	0.37 (U)	0.06 (U)	NC	NC
199-N-34	69.3	53.5	67	44	37	57.4	45	42	42	35.9	-48	-33
199-N-41	0.004 (U)	-0.10 (U)	-0.41 (U)	-1.20 (U)	-1.80 (U)	0.50 (U)	1	NS	0.48 (U)	0.50 (U)	NC	NC
199-N-46	5,850	2,690	630	580	530	1,220	1,035	1,400	1,570	1,730	-70	-36
199-N-50	-0.02 (U)	NS	NS	NS	-0.20 (U)	-0.13 (U)	0.23 (U)	0.8 (U)	0.17 (U)	0.73	NC	NC
199-N-51	0.254 (U)	0.11 (U)	NS	N	-5.30 (U)	0.52 (U)	0.26 (U)	0.78 (U)	0.16 (U)	-0.54 (U)	NC	NC
199-N-56	164[b]	317	170	140	-7.5 (U)	490	560	380	338	246	50	-22

Table 4-2. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/ Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	2015 (pCi/L)	Percent Change, 1994 to 2015	Percent Change 2005 to 2015
199-N-57	26	9.71	8.51	2.90	5.80	15.2	15.5	12	10	6.86	-74	-29
199-N-64	0.185 (U)	0.785 (U)	0.256 (U)	-5.30 (U)	-4.60 (U)	0.48 (U)	3	0.49 (U)	1.2 (U)	0.35 (U)	NC	NC
199-N-67	3,680	9,710	10,000	9,000	9,800	13,500	11,550	14,000	15,500	13,600	270	40
199-N-69[c]	-0.09 (U)	0.21 (U)	NS	NS	-3.20 (U)	2.96	12	4.8	3	0.57 (U)	NC	NC
199-N-70[c]	0.321 (U)	0.156 (U)	-2.60 (U)	-2.40 (U)	-3.80 (U)	0.79	1.2	1.2	0.54 (U)	-0.27 (U)	NC	NC
199-N-71	0.55	NS	0.38 (U)	-0.05 (U)	-2.80 (U)	-3.90 (U)	0.29 (U); 1.1	0.65 (U)	0.60 (U)	0.27 (U)	NC	NC
199-N-72	2.59[d]	NS	-1.00 (U)	NS	-1.70 (U)	-2.60 (U)	NS	NS	NS	NS	NC	NC
199-N-73	0.53	NS	NS	NS	NS	NS	NS	NS	NS	NS	NC	NC
199-N-74	0.415	-0.08 (U)	2.3[d]	405[d]	-2.0 (U)	-3.60 (U)	NS	NS	NS	NS	NC	NC
199-N-75[e]	2,110	307	2,500	3,000	2,400	NS	3,200	2,500	2,540	3,200	52	942
199-N-76	84.9	216	180	180	120	387	1,120	690	440	177	108	-18
199-N-77	0.45	NS	NS	NS	NS	NS	NS	NS	NS	NS	NC	NC
199-N-80[c]	0.734 (Q)	-0.154 (U)	0.82 (U)	-0.07 (U)	-5.9 (U)	0.22 (U)	0.77 (U)	1.5	2	0.06 (U)	NC	NC
199-N-81	746	734	970	400	320	395	450	490	475	513	-31	-30
199-N-92A	0.59 (U)	0.92	1.22	3.50	-9 (U)	0.60	0.47 (U)	0.69 (U)	1	-0.05 (U)	NC	NC
199-N-96A	4.90[f]	5.74	1.65	-1.30 (U)	3.94	9.90	2.04	5.9	2	4.36	-11	-24
199-N-99A	2,860[f]	1,270	1,200	1,400	1,500	1,020	666.5	1,230	1,600	1,540	-46	21
199-N-103A[e,g]	4.08[f]	422	1,200	1,200	1,400	1,360	1,600	1,300	1,420	1,560	NC	270

Table 4-2. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/ Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	2015 (pCi/L)	Percent Change, 1994 to 2015	Percent Change 2005 to 2015
199-N-104A	5.68[f]	NS	NS	NS	NS	NS	380	260	NS	NS	NC	NC
199-N-105A[e,g]	112[f]	1,360	1,900	1,500	1,600	6,580	6,100	1,900	2,210	1,150	NC	-15
199-N-106A[e,g]	2,890[f]	3,260	2,200	1,800	NS	2,370	3,035	2,200	2,240	1,580	-45	-52
199-N-119	—	280	250	210	220	274	56	41	29	14.5	NC	-95
199-N-120[c]	—	10.1	6.55	NS	1.40 (U)	6.93	58	5.7	4	1.93	NC	-81
199-N-121[c]	—	0.272 (U)	0.0169 (U)	NS	-2.00 (U)	-0.02 (U)	0.23 (U)	-0.21 (U)	0.33 (U)	0.52 (U)	NC	NC
199-N-122	—	730	1,160	260	800	740	656	560	907	1,100	NC	51
199-N-123	—	871	255	-1.60 (U)	280	1,770	204	140	120	55.8	NC	-94
199-N-146	—	318[h]	412	260	300	328	215	270	256	200	NC	-37
199-N-147	—	522[h]	791	250	250	478	250	120	231	157	NC	-70
199-N-165	—	—	—	-1.90 (U)	-6.60 (U)	0.14 (U)	0.57 (U)	1.6	-0.39 (U)	0.24 (U)	NC	NC
199-N-173	—	—	—	16	23	19	14.5	22	25	21.5	NC	NC
199-N-182	—	—	—	—	—	—	110	140	144	83.9	NC	NC
199-N-183	--	--	--	—	—	—	120	100	82	81.2	NC	NC
199-N-184	—	—	—	—	—	—	5,000	1,100	1,150	320	NC	NC
199-N-185	—	—	—	—	—	—	3.9	7.6	8	6.43	NC	NC
199-N-186	—	—	—	—	—	—	810	390	420	207	NC	NC
199-N-187	—	—	—	—	—	—	8,600	11,400	12,800	9,860	NC	NC
199-N-188	—	—	—	—	—	—	1,500	2,500	2,280	1,520	NC	NC

Table 4-2. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/ Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	2015 (pCi/L)	Percent Change, 1994 to 2015	Percent Change 2005 to 2015
199-N-189	—	—	—	—	—	—	0.02 (U)	0.39 (U)	0.85 (U)	0.27 (U)	NC	NC
Aquifer Tubes												
C7934	—	—	—	—	300	NS	93	310	321	344	NC	NC
C7935	—	—	—	—	300	NS	190	280	356	331	NC	NC
C7936	--	—	—	—	69	NS	55	96	83	80.4	NC	NC
APT-1	—	3,400[h]	NS	NS	500	530	840	270	211	331	NC	-90
APT-5	—	2,100[h]	NS	NS	450	420	270	120	184	238	NC	-89
N116mArray-3A	—	379	1,750[d]	500	110	248	240	170	190	120	NC	-68
N116mArray-4A	—	1,260	7,000[d]	340	270	226	250	280	342	186	NC	-85
NVP2-116.0	—	3,200	2,550[d]	1,100	1,200	1,100	733	700	845	1,680	NC	-48
N116mArray-6A	—	477	370[d]	95[d]	110	170	190	130	251	75.2	NC	-84

Notes: Data are reported from the fall of the year, unless otherwise noted.

Cells with "—" indicated the well or aquifer tube was constructed after this date

Yellow-shaded cells indicate wells with concentrations above the drinking water standard (8 pCi/L).

a. Sampled on 1/20/2015.

b. Not sampled in 1994; value from 1993 used for table.

c. Screened at depth in Ringold Formation.

d. Value calculated from gross-beta data (no strontium-90 data available); value listed is one-half of the gross-beta value measured.

e. Former P&T extraction well.

f. Not sampled in 1994; value from 1995 used for table.

Table 4-2. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/ Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	2015 (pCi/L)	Percent Change, 1994 to 2015	Percent Change 2005 to 2015

g. A P&T system was operated from 1995 through 2006.

h. Not sampled in 2005; value from 2006 used for table.

NC = not calculated

NS = not sampled

P&T = pump and treat

Q = associated with out-of-limits quality control samples

TPH = total petroleum hydrocarbon-diesel

U = nondetect

Table 4-3. Performance Monitoring at the Apatite PRB, 100-NR-2 OU

Well Name	Number of Baseline Samples	Number of Baseline Nondetects	Strontium-90 Concentration (pCi/L)				Percent Reduction in Strontium-90 (Baseline Maximum to 2015)[c]	
			Minimum Detected Baseline	Maximum Baseline	Spring 2015[a]	Fall 2015[b]		
Upriver Apatite Permeable Reactive Barrier								
			04/06/10		**June 2015**	**Sept 2015**	**Spring**	**Fall**
199-N-96A	56	8	1.54[d]	37.9[d]	3.2	4.4	92	88
199-N-347	1	1	7[e]	7[e]	5.2	4.2	26	40
199-N-348	1	0	1,800	1,800	91.4	50.3	95	97
199-N-349	2	0	220	230	92.7	130	60	43
Central (Original) Apatite Permeable Reactive Barrier								
(See footnote f)			(See footnote g)		**June 2015**	**Sept 2015**	**Spring**	**Fall**
199-N-122	10	0	657	4,630	518	1100	89	76

Table 4-3. Performance Monitoring at the Apatite PRB, 100-NR-2 OU

Well Name	Number of Baseline Samples	Number of Baseline Nondetects	Strontium-90 Concentration (pCi/L)				Percent Reduction in Strontium-90 (Baseline Maximum to 2015)[c]	
			Minimum Detected Baseline	Maximum Baseline	Spring 2015[a]	Fall 2015[b]		
199-N-146	4	0	318	985	169	200	83	80
199-N-147	3	0	522	1,842	191	157	90	91
199-N-123	6	0	689	1,180	116	55.8	90	95
Downriver Apatite Permeable Reactive Barrier								
			07/28/10 and 07/29/10		**June 2015**	**Sept 2015**	**Spring**	**Fall**
199-N-350	1	0	240	240	67.9	83.5	72	65
199-N-351	1	0	350	350	272	479	22	0
199-N-352	1	0	580	580	166	569	71	2
199-N-353	1	0	83	83	3.0	11.5	96	86

a. Spring 2015 samples were collected from June 7 through June 18.

b. Fall 2015 samples were collected from September 18 through September 30.

c. The percentage reduction in strontium-90 concentration is calculated as: (([baseline value] – [2015 value])/[baseline value]) × 100. Maximum baseline value used for comparison.

d. Between 1995 and 2011, the maximum baseline was measured on 12/06/1995; the minimum detected baseline was measured on 06/13/2006 and 06/22/2007.

e. Strontium-90 is a beta emitter. Gross beta concentrations are approximately two times the strontium-90 concentrations. The strontium-90 concentration was 1.1 U pCi/L. The gross beta concentration, 14 pCi/L, was divided by two to approximate the strontium-90 concentration of 7 pCi/L.

f. From Table 8.1 in PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*.

g. From Table 4.1 in PNNL-19572, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*.

Table 4-4. Apatite PRB Performance Monitoring Wells and Aquifer Tubes

Well Name/ID	Well Type	Well Name/ID	Well Type	Well Name/ID	Well Type
C6132	AT	NVP2-116.0m/C5251	AT	N116mArray-10A/C5264	AT
199-N-173/C7038	MW	N116mArray-6A/C5259	AT	199-N-359/C7452	MW
N116mArray-0A/C5514	AT	199-N-147/C5116	MW	N116mArray-11A/C5265	AT
199-N-346/C7442	MW	APT-5/C5386	AT	199-N-360/C7453	MW
C6135	AT	199-N-350/C7443	MW	N116mArray-12A/C5266	AT
199-N-96A/A9882	MW			199-N-361/C7454	MW
C6136	AT	C7881*	AT	199-N-362/C7455	MW
199-N-347/C7441	MW	199-N-351/C7444	MW	199-N-363/C7456	MW
N116mArray-1A/C5255	AT	199-N-352/C7445	MW	N116mArray-13A/C5267	AT
199-N-348/C7440	MW	199-N-353/C7446	MW	199-N-364/C7457	MW
N116mArray-2A/C5256	AT	N116mArray-8A/C5261	AT	199-N-365/C7458	MW
199-N-349/C7439	MW	199-N-354/C7447	MW	N116mArray-14A/C5268	AT
199-N-123/C4955	MW	N116mArray-8.5A/C5262	AT	199-N-366/C7459	MW
APT-1/C5269	AT	199-N-355/C7448	MW	199-N-367/C7463	MW
N116mArray-3A/C5257	AT	199-N-356/C7449	MW	199-N-92A/A8878	MW
199-N-146/C5052	MW	199-N-357/C7450	MW	N116mArray-15A/C5512	AT
N116mArray-4A/C5258	AT	N116mArray-9A/C5263	AT		
199-N-122/C4954	MW	199-N-358/C7451	MW		

Note: Yellow shading indicates locations currently being monitored for treated portion of barrier.

* Aquifer tube N116mArray-7A was monitored from June 2006 through September 2009. The aquifer tube became unusable in 2009 and was replaced with C7881at the same location.

AT = aquifer tube   MW = monitoring well (6 in.)   ID = identification

Table 4-5. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
199-N-200/C7327	Shallow	199-N-222/C7305	Shallow; core	199-N-144/C5050	Shallow, deep	199-N-250/C7343	Deep
199-N-201/C7326	Deep	199-N-223/C7304	Deep	199-N-161/C6179	Deep	199-N-251/C7344	Shallow
199-N-202/C7325	Shallow	199-N-224/C7303	Shallow	199-N-145/C5051	Shallow, deep	199-N-252/C7345	Deep
199-N-203/C7324	Deep	199-N-225/C7302	Deep	199-N-160/C6178	Deep	199-N-253/C7346	Shallow
199-N-204/C7323	Shallow	199-N-226/C7301	Shallow	199-N-136/C5042	Shallow, deep	199-N-254/C7347	Deep
199-N-205/C7322	Deep	199-N-227/C7300	Deep	199-N-159/C6177	Deep	199-N-255/C7348	Shallow
199-N-206/C7321	Shallow	199-N-228/C7299	Shallow	199-N-137/C5043	Shallow, deep	199-N-256/C7349	Deep
199-N-207/C7320	Deep	199-N-229/C7298	Deep	199-N-235/C7328	Shallow	199-N-257/C7350	Shallow
199-N-208/C7319	Shallow	199-N-230/C7297	Shallow	199-N-236/C7329	Deep	199-N-258/C7351	Deep
199-N-209/C7318	Deep	199-N-231/C7296	Deep	199-N-237/C7330	Shallow	199-N-259/C7352	Shallow
199-N-210/C7317	Shallow	199-N-232/C7295	Shallow	199-N-238/C7331	Deep	199-N-260/C7353	Deep
199-N-211/C7316	Deep	199-N-233/C7294	Deep	199-N-239/C7332	Shallow	199-N-261/C7354	Shallow
199-N-212/C7315	Shallow	199-N-234/C7293	Shallow	199-N-240/C7333	Deep	199-N-262/C7355	Deep
199-N-213/C7314	Deep	199-N-138/C5044	Shallow, deep	199-N-241/C7334	Shallow	199-N-263/C7356	Shallow
199-N-214/C7313	Shallow	199-N-139/C5045	Shallow, deep	199-N-242/C7335	Deep	199-N-264/C7357	Deep
199-N-215/C7312	Deep	199-N-140/C5046	Shallow, deep	199-N-243/C7336	Shallow	199-N-265/C7358	Shallow
199-N-216/C7311	Shallow	199-N-141/C5047	Shallow, deep	199-N-244/C7337	Deep	199-N-266/C7359	Deep
199-N-217/C7310	Deep; core	199-N-164/C182	Deep	199-N-245/C7338	Shallow	199-N-267/C7360	Shallow
199-N-218/C7309	Shallow	199-N-142/C5048	Shallow, deep	199-N-246/C7339	Deep	199-N-268/C7361	Deep

Table 4-5. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
199-N-219/C7308	Deep; core	199-N-163/C6181	Deep	199-N-247/C7340	Shallow	199-N-269/C7362	Shallow
199-N-220/C7307	Shallow; core	199-N-143/C5049	Shallow, deep	199-N-248/C7341	Deep	199-N-270/C7363	Deep
199-N-221/C7306	Deep	199-N-162/C6180	Deep	199-N-249/C7342	Shallow	199-N-271/C7364	Shallow
199-N-272/C7365	Deep	199-N-291/C7384	Shallow	199-N-310/C7403	Deep	199-N-329/C7422	Shallow
199-N-273/C7366	Shallow	199-N-292/C7385	Deep	199-N-311/C7404	Shallow	199-N-330/C7423	Deep
199-N-274/C7367	Deep	199-N-293/C7386	Shallow	199-N-312/C7405	Deep	199-N-331/C7424	Shallow
199-N-275/C7368	Shallow	199-N-294/C7387	Deep	199-N-313/C7406	Shallow	199-N-332/C7425	Deep
199-N-276/C7369	Deep	199-N-295/C7388	Shallow	199-N-314/C7407	Deep	199-N-333/C7426	Shallow
199-N-277/C7370	Shallow	199-N-296/C7389	Deep	199-N-315/C7408	Shallow	199-N-334/C7427	Deep
199-N-278/C7371	Deep	199-N-297/C7390	Shallow	199-N-316/C7409	Deep	199-N-335/C7428	Shallow
199-N-279/C7372	Shallow	199-N-298/C7391	Deep	199-N-317/C7410	Shallow	199-N-336/C7429	Deep
199-N-280/C7373	Deep	199-N-299/C7392	Shallow	199-N-318/C7411	Deep	199-N-337/C7430	Shallow
199-N-281/C7374	Shallow	199-N-300/C7393	Deep	199-N-319/C7412	Shallow	199-N-338/C7431	Deep
199-N-282/C7375	Deep	199-N-301/C7394	Shallow	199-N-320/C7413	Deep	199-N-339/C7432	Shallow
199-N-283/C7376	Shallow	199-N-302/C7395	Deep	199-N-321/C7414	Shallow	199-N-340/C7433	Deep
199-N-284/C7377	Deep	199-N-303/C7396	Shallow	199-N-322/C7415	Deep	199-N-341/C7434	Shallow
199-N-285/C7378	Shallow	199-N-304/C7397	Deep	199-N-323/C7416	Shallow	199-N-342/C7435	Deep
199-N-286/C7379	Deep	199-N-305/C7398	Shallow	199-N-324/C7417	Deep	199-N-343/C7436	Shallow
199-N-287/C7380	Shallow	199-N-306/C7399	Deep	199-N-325/C7418	Shallow	199-N-344/C7437	Deep

Table 4-5. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
199-N-288/C7381	Deep	199-N-307/C7400	Shallow	199-N-326/C7419	Deep	199-N-345/C7438	Shallow
199-N-289/C7382	Shallow	199-N-308/C7401	Deep	199-N-327/C7420	Shallow		
199-N-290/C7383	Deep	199-N-309/C7402	Shallow	199-N-328/C7421	Deep		

Notes: "Core" indicates that a core was taken at this well for jet injection study (2010).

Blue shading indicates downriver barrier extension wells treated in September 2011.

Green shading indicates original barrier wells treated in 2006 through 2008.

Pink shading indicates upriver barrier extension wells treated in September 2011.

No shading indicates that wells are not treated yet.

Wells identified with Shallow depth are screened in the upper region (typically about 2 m [6 ft]) of the unconfined aquifer; wells identified with Deep depth are screened below the shallow wells (typical screen length of 2.5 m (8 ft) about 0.6 m (2 ft) below the depth of shallow screened wells; wells identified with Shallow, deep depths are screened across both the shallow and deep depths.

ID = identification

Table 4-6. PRB Monitoring Well 2011 - 2015 Performance Summary

Monitoring Well	Pre-injection Baseline[a]	Mo-Yr Treated	Concentration (pCi/L) (Percent Reduction from Baseline[b])				
			2011	2012	2013	2014	2015
Upriver Apatite Permeable Reactive Barrier (Treated 2011)							
199-N-96A	37.9	Sep 2011	--[c]	2.3 (94%)	4.1 (89%)	1.6 (96%)	3.8 (90%)
199-N-347	7[d]	Sep 2011	--[c]	7.8 (-12%)	6.9 (1.4%)	5.1 (27%)	4.7 (33%)
199-N-348	1,800	Sep 2011	--[c]	54 (97%)	34 (98%)	35 (98%)	71 (96%)
199-N-349	230	Sep 2011	--[c]	37 (84%)	46 (80%)	87 (62%)	111 (52%)
Central (Original) Apatite Permeable Reactive Barrier (Treated 2006-2008)							
199-N-122	4,630	Jul 2008	366 (93%)	656 (86%)	472 (90%)	637 (86%)	809 (82%)
199-N-146	985	Jul 2008	204 (79%)	215 (78%)	225 (77%)	204 (79%)	184 (81%)
199-N-147	1,842	Jul 2008	272 (85%)	250 (86%)	135 (93%)	230 (88%)	174 (90%)
199-N-123	1,180	Jul 2008	704 (40%)[e]	204 (83%)	125 (89%)	91 (92%)	96 (92%)
Downriver Apatite Permeable Reactive Barrier (Treated 2011)							
199-N-350	240	Sep 2011	--[c]	34 (86%)	21 (91%)	27 (89%)	76 (68%)
199-N-351	350	Sep 2011	--[c]	26 (93%)	39 (89%)	95 (73%)	376 (-7%)
199-N-352	580	Sep 2011	--[c]	30 (95%)	29 (95%)	42 (93%)	368 (37%)
199-N-353	83	Sep 2011	--[c]	5.0 (94%)	3.2 (96%)	4.0 (95%)	7.3 (91%)

a. Pre-injection baseline concentrations for the upriver and downriver PRB monitoring wells area based on samples collected in 2010. Pre-injection baseline concentrations for the central PRB monitoring wells are from Table 4.1 in PNNL-19572, 100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization.

b. The percentage reduction in strontium-90 concentration is calculated as ([pre-injection value] – [average value for the year] / [pre-injection value]) × 100.

c. Injections were performed in September 2011 so no performance calculated for this year.

d. Strontium-90 is a beta emitter. Gross-beta concentrations are approximately two times the strontium-90 concentrations. The strontium-90 concentration was 1.1 pCi/L (U). The gross beta concentration, 14 pCi/L, was divided by two to approximate the strontium-90 concentration of 7 pCi/L.

e. Increase in strontium-90 concentrations observed at monitoring well 199-N-123 in 2011 is attributed to injection treatment of the upriver segment in September 2011.

PRB = permeable reactive barrier

Table 4-7. PRB Aquifer Tube 2011 - 2015 Performance Summary

Aquifer Tube	Pre-injection Baseline[a]	Mo-Yr Treated	Concentration (pCi/L) (Percent Reduction from Baseline[b])				
			2011	2012	2013	2014	2015
Upriver Apatite Permeable Reactive Barrier (Treated 2011)							
C6135[c]	2.3	Sep 2011	1.5 (33%)	2.8 (-21%)	--[d]	--[d]	--[d]
N116mArray-1A	34	Sep 2011	94 (-171)[e]	162 (-369)[e]	50 (-45%)[e]	2.1 (94%)	1.9 (94%)
N116mArray-2A	199	Sep 2011	244 (-22%)[e]	29 (85%)	16 (92%)	16 (92%)	17 (92%)
Central (Original) Apatite Permeable Reactive Barrier (Treated 2006-2008)							
APT-1	1,454	Jul 2008	530 (64%)	575 (60%)	235 (84%)	184 (87%)	276 (81%)
APT-5	420	Jul 2008	420 (3%)	196 (55%)	97 (78%)	149 (66%)	202 (53%)
N116mArray-3A	379	Jul 2008	185 (52%)	202 (47%)	185 (52%)	162 (58%)	125 (67%)
N116mArray-4A	1,220	Jul 2008	230 (81%)	207 (83%)	215 (82%)	245 (80%)	202 (83%)
N116mArray-6A	445	Jul 2008	203 (54%)	205 (54%)	126 (72%)	119 (73%)	106 (76%)
NVP2-116.0	3,466	Jul 2008	1,078 (69%)	588 (83%)	633 (82%)	639 (82%)	1,146 (67%)
Downriver Apatite Permeable Reactive Barrier (Treated 2011)							
N116mArray-7A/ C7881[f]	336	Sep 2011	755 (-124%)[e]	73 (78%)	32 (91%)	23 (93%)	27 (92%)
N116mArray-8A	7.8	Sep 2011	8.9 (-16%)[e]	2.4 (68%)	1.7 (78%)	1.3 (83%)	1.7 (78%)

a. Pre-injection baseline concentrations are based 95 upper confidence limit of pre-injection strontium-90 and gross beta measurements. Strontium-90 is a beta emitter. Gross-beta concentrations are approximately two times the strontium-90 concentrations. The gross beta concentrations were divided by two to approximate the strontium-90 concentration in determining pre-injection baseline concentrations.

b. The percentage reduction in strontium-90 concentration is calculated as ([pre-injection value] – [average value for the year] / [pre-injection value]) × 100.

c. Concentrations at C6135 are below the DWS (8 pCi/L).

d. Aquifer tube is missing and/or in need of repair and could not be sampled

e. Increased concentrations at aquifer tube attribute to residual spike from injection treatment

f. Aquifer tube C7881 is a replacement for N16mArray-7A installed in the same location.

DWS = drinking water standard

Table 4-8. Injection Volume in Upriver Injection Wells Near Well 199-N-349

Injection Well	Screen/Formation	Injected Volume (gal)
199-N-225	Deep/Backfill	86,511
199-N-226	Shallow/Backfill	84,653
199-N-227	Deep/Backfill	97,368
199-N-228	Shallow/Ringold	91,915
199-N-229	Deep/Hanford	149,822
199-N-230	Shallow/Ringold	23,891
199-N-231	Deep/Ringold	32,423

Table 4-9. Injection Volume in Downriver Injection Wells near Wells 199-N-350, 199-N-351, and 199-N-352

Injection Well	Screen/Formation	Injected Volume (gal)
199-N-237	Shallow/Ringold	21,051
199-N-238	Deep/Ringold	92,816
199-N-239	Shallow/Ringold	1,499
199-N-240	Deep/Ringold	22,611
199-N-241	Shallow/Ringold	29,714
199-N-242	Deep/Ringold	13,676
199-N-243	Shallow/Ringold	23,211
199-N-244	Deep/Ringold	15,473
199-N-245	Shallow/Ringold	65,364
199-N-246	Deep/Ringold	69,965
199-N-247	Shallow/Ringold	6,164
199-N-248	Deep/Ringold	62,361
199-N-249	Shallow/Ringold	61,216
199-N-250	Deep/Ringold	67,810
199-N-251	Shallow/Ringold	115,411
199-N-252	Deep/Ringold	57,904

Table 4-10. PRB Performance Evaluation Summary

Assessed Treated PRB Length	Treated PRB	Upriver Segment	Original Segment	Downriver Segment
Total length of Treated PRB	311 m (1,020 ft)	110 m (360 ft)	91 m (300 ft)	110 m (360 ft)
Length identified as "Green – continued Sr-90 reduction" Percent of Treated PRB "Green"	206 m (675 ft) 66% of treated PRB	87 m (285 ft) 79% of segment	91 m (300 ft) 100% of segment	28 m (90 ft) 5% of segment
Length identified as "Yellow – Below Target Reduction with increasing trend" Percent of Treated PRB "Yellow"	55 m (180 ft) 18% of treated PRB	23 m (75 ft) 21% of segment	0 m (0 ft) 0% of segment	32 m (105 ft) 29% of segment
Length identified as "Red – Performance Compromised" Percent of Treated PRB "Red"	50 m (165 ft) 16% of treated PRB	0 m (0 ft) 0% of segment	0 m (0 ft) 0% of segment	50 m (165 ft) 46% of segment

PRB = permeable reactive barrier

Table 4-11. Petroleum Hydrocarbon Releases in the 100-N Area

Group	WIDS Number	Location	Description
Group 1 – 166-N & 1715-N	UPR-100-N-17	166-N diesel oil supply line leak	In August 1966, an estimated 302,832 L (80,000 gal) of diesel leaked from a failed transfer system near the 166-N facility. In August 1967, J.M. Shelby documented the possible impacts on the Columbia River. Diesel was slipping from the bluff below the 166-N Tank Farm and into the river. A trench was excavated below the bluff to collect the diesel to be burned off; WIDS site 100-N-65 diesel burn trench (BNWL-CC-1296; UNI-228).
	UPR-100-N-18	166-N diesel oil supply line leak	In August 1973, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line between 166-N and 184-N facilities (PNL-6456; UNI-228).

Table 4-11. Petroleum Hydrocarbon Releases in the 100-N Area

Group	WIDS Number	Location	Description
	UPR-100-N-20	166-N diesel oil supply line leak	In June 1985, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line near Tank 1 in the 166-N facility (UNI-228).
	UPR-100-N-24	166-N diesel oil supply line leak	On February 1, 1987, a line leak was reported. Petroleum product type and quantity were not reported. No further information is available (WHC-SD-EN-TI-251).
Group 3 – 184-N	UPR-100-N-42	184-N Day Tank area liquid unplanned release	On October 9, 1987, an unspecified quantity of petroleum material with an unspecified description was documented around the 184-N facility day tanks (WIDS).
	UPR-100-N-19	184-N Day Tank fuel oil line leak	In April 1984, an estimated 28,391 L (7,500 gal) of No. 6 fuel oil leaked at the 184-N Day Tank facility. It was reported that all the fuel oil stayed within the tank confinement basin and did not penetrate the hard-packed sand bottom. Waste oil was removed and disposed (UNI-228).
	UPR-100-N-21	184-N Diesel Oil Day Tank overflow	On April 25, 1986, an estimated 3,028 L (800 gal) of diesel oil spilled into the area surrounding a day tank at 184-N. Approximately 2,461 L (650 gal) were reported as pumped/cleaned up. Nearby monitoring Well 199-N-16 reported no detections (WIDS).
	UPR-100-N-22	Diesel oil supply line leak No. 1	On June 23, 1986, an estimated 3,785 L (1,000 gal) of diesel oil leaked from a transfer line. This release was detected in nearby Well 199-N-16 (WIDS). An unspecified quantity of petroleum material was pumped from the well (WHC-SD-EN-TI-251).
	UPR-100-N-23	Diesel oil supply line leak No. 2	On January 10, 1987, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line. This release was detected in nearby Well 199-N-16. An unspecified quantity of petroleum material was pumped from the well (WHC-SD-EN-TI-251).
	100-N-12	184-N Pipeline spill	A spill inside the 184-N Pipeline that leaked to the outside occurred on October 14, 1987. An unknown amount of fuel oil leaked from a loose pipe fitting at the 184-N Annex. Spill was contained in a drain trench and cleaned up (WIDS).

Table 4-11. Petroleum Hydrocarbon Releases in the 100-N Area

Group	WIDS Number	Location	Description
Group 2 – Other Miscellaneous Sites	UPR-100-N-43	166-N to 184-N Transfer Line multiple leak	Diesel oil leaks occurred at three locations along a pipeline from 166-N to 184-N at three different flange points. The exact locations of the flange points were not provided. The release was reported on April 26, 1989. In total, 46 drums and 8 dump trucks of contaminated soil were removed. Sampling was conducted in nearby Wells 199-N-16 and 199-N-17 and oil was detected. Reported as cleaned up by April 26, 1989 (DOE/RL-90-22; WHC-C-89-047-100N-20).
	UPR-100-N-36	184-N Annex diesel generator area release	During excavation between 184-N and 153-N (area of approximately 40 m by 18 m (130 ft by 60 ft), a strong smell of petroleum was noted. Neither date nor quantity of material is reported (WIDS).
	100-N-36	Oil-stained pad (near 107-N Building)	This site was once used to support an air compressor. Neither date nor amount of petroleum material leaked is available; however, available documentation suggests that the quantity was minimal and limited to the soil immediately beneath the pad. The small amount of petroleum released may have leaked to the ground through a crack between the concrete pads and asphalt (WIDS).
	100-N-35	Hanford Generating Plant/Bonneville Power Administration Switchyard	This portion of the 100-N Area is still in use by the Bonneville Power Administration and is reported to contain spills of oil materials that could contain polychlorinated biphenyls.
	100-N-65	Diesel burn pit adjacent to river	This site was a trench/pit excavated adjacent to the river to intercept and burn diesel oil before it could significantly affect the Columbia River (refer to UPR-100-N-17). In 1994, the trench was backfilled with material to the top of the adjacent berm (WIDS).
	124-N-2	182-N Septic System	This site was a septic system east of 182-N that was reported to have had petroleum introduced into it. This site includes a septic tank and seepage pit and was reported pumped and isolated after the 124-N-10 Septic Treatment Facility was placed in service in February 1987 (WIDS).

Sources: BNWL-CC-1296, *Environmental Significance of Diesel Fuel Entering Columbia River at 100-N*.

DOE/RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington*.

PNL-6456, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford: Volume 1 – Evaluation Methods and Results*.

UNI-228, *Oil Spill Prevention, Control, and Countermeasures Plan*.

WHC-C-89-047-100N-20, *Critique Report, 184-N Powerhouse Diesel Oil Leak (April 26, 1989)*.

WHC-SD-EN-TI-251, *100-N Area Technical Baseline Report*.

WIDS = Waste Information Data System

Table 4-12. TPH-D Concentrations (C10-C20) (µg/L) for Bioventing Performance Monitoring Wells and Aquifer Tubes

Date	Bioventing Air Injection Wells		Bioventing Monitoring Wells							Upgradient Well	Aquifer Tubes	
	199-N-167	199-N-172	199-N-3	199-N-19	199-N-96A	199-N-169	199-N-171	199-N-173	199-N-183	199-N-56	C6132	N116mArray-0A
January 2015	447	2,500	47.6 (U)	103 (J)	52.1 (U)	576	2,880	647	1,060	75.9 (J)	48.1 (U)	650[a]
July 2015	927 (T)	4,130	47.6 (U)	143 (J,T)	161 (J,T)	545 (T)	4,360 (D,T)	1,280 (T)	2,180 (T)	233 (T)	82.6 (J)	500[b]

a. Sample collected from N116mArray-0A on December 29, 2014 as part of annual 100-NR-2 Operable Unit groundwater monitoring.

b. Unable to sample N116mArray-0A in July because aquifer tube needed repairs. Sample collected from N116mArray-0A on December 7, 2015 after repairs were completed.

D = analyte was identified in an analysis at a secondary dilution factor

J = estimated

T = spike and/or spike duplicate sample recovery is outside control limits

U = analyzed for but not detected above reporting limit

Table 4-13. Petroleum Hydrocarbon Removal from Well 199-N-18

Year	Product Removed (g)	Notes
2003[a]	~1,200[b]	Estimate provided per information given in table note; data records lost when original work package was lost in the field.
2004	3,475	Changed out twice per month.
2005	780	Changed approximately every 2 months.
2006	1,370	Changed every 2 months.
2007	1,294	Changed every 2 months.
2008	920	Changed every 2 months.
2009	1,380	Changed approximately every 2 months.
2010	225.5	Changed only twice prior to June 2010; smart sponge broke apart in well. No removal for second half of 2010.
2011	500	Changed every 2 months.
2012	600	Changed in January, April, June, and August 2012.
2013	750	Changed in January, March, May, July, September, and November 2013.
2014	550	Changed in February, April, June, August, and October 2014.
2015	1,050	Changed in January (twice), April, June, July, September, and December (twice) 2015
Total		**14,094.5 grams (approximately 14 kg) removed through end of 2015**

a. DOE/RL-2004-21, *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations*, reports that product removal began in October 2003.

b. DOE/RL-2005-18, *Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, states that the average mass removal for fiscal year 2004 (October 2003 through October 2004) was approximately 0.4 kg/month; therefore, an estimate is provided for the 3 months missing in 2003.

Table 4-14. Maximum TPH-D Concentrations for Selected Wells and Aquifer Tubes

Date	199-N-3	199-N-16	199-N-18	199-N-183	199-N-19	199-N-21	199-N-56	199-N-57	199-N-96A	199-N-173	116m Array-0A	C6135	116m Array-1A
1992	NR	200 (U)	NR	N/A	200 (U)	200 (U)	1,000 (U)	NR	NR	NR	NR	NR	NR
1993	1,000 (U)	67 (J)	NR	N/A	100 (U)	100 (U)	NR	100 (U)	NR	NR	NR	NR	NR
1994	1,000	4,000	NR	N/A	500 (U)	1,000	NR	NR	NR	NR	NR	NR	NR
1995 to 1998	NR	NR	NR	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR
1999	NR	NR	16,000 (D)	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR
2000	92 (U)	NR	23,000 (D,N)	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR
2001	92 (U)	NR	6,800,000 (D,N)	N/A	NR	NR	NR	NR	50 (U)	NR	NR	NR	NR
2002	50 (U)	NR	440,000 (D,N)	N/A	50 (U)	NR	NR	NR	1,500	NR	NR	NR	NR
2003	50 (U)	6,500 (N)	630,000,000 (D,Z)	N/A	50 (U)	NR	NR	NR	900	NR	NR	NR	NR
2004	50 (U)	6,100 (N)	340,000 (D,N)	N/A	50 (U)	60 (U,H)	60 (U)	NR	750 (N)	NR	NR	NR	NR
2005	50 (U)	11,000 (N)	69,000 (D,N)	N/A	580 (N,Q)	50 (U)	50 (U)	NR	610	NR	NR	NR	NR
2006	50 (U)	50 (U)	23,000 (D)	N/A	50 (U)	50 (U)	50 (U)	NR	50 (U)	NR	NR	NR	50 (U,D)
2007	50 (U)	33 (U,D,N)	190,000	N/A	50 (U)	71 (U)	50 (U)	NR	50 (U)	NR	970	290	15 (U)
2008	33 (U)	NR	809,000 (D)	N/A	72 (U)	NR	NR	NR	71 (U)	NR	94 (U)	320	72 (U)

Table 4-14. Maximum TPH-D Concentrations for Selected Wells and Aquifer Tubes

Date	199-N-3	199-N-16	199-N-18	199-N-183	199-N-19	199-N-21	199-N-56	199-N-57	199-N-96A	199-N-173	116m Array-0A	C6135	116m Array-1A
2009	17 (U)	70 (U)	67,000 (D)	N/A	17 (U)	70 (U)	70 (U)	70 (U)	260	2,100	840	770	70 (U)
2010	70 (U)	79 (J)	420,000 (D)	N/A	70 (U)	70 (U)	70 (U)	70 (U)	200 (X)	2,100	570	910	200
2011	70 (U)	70 (U)	48,000 (H)	N/A	670	70 (U)	70 (U)	70 (U)	70 (U)	70 (U)	360	670	80 (U)
2012	70 (U)	70 (U)	Not sampled[a]	2,100 (X)	70 (U)	70 (U)	70 (U)	70 (U)	140	1,900	440	870 (X)	70 (U)
2013[b]	70 (U)	—[c]	Not sampled[a]	3,350 (X)	70 (U)	70 (U)	70 (U)	70 (U)	70 (U)	410	880	—[d]	70 (U)
2014	51 (U)	—[c]	Not sampled[a]	2,600 (T)	108 (J)	Not sampled	112 (J,T)	17 (U)	446 (T)	4,700 (T)	2,200 (T)	—[d]	47.6 (U)
2015	48 (U)	—[c]	Not sampled[a]	2,180 (T)	143 (J,T)	48 (U)	233 (T)	50 (U)	161 (J,T)	1,280 (T)	800	—[d]	92 (J)

Note: Highest detected result or lowest nondetectable result for a calendar year are reported in this table.

a. Well 199-N-18 was replaced by 199-N-183 for groundwater sampling

b. Does not include results in WCH-600, *Annual Operations and Monitoring Report for UPR-100-N-17: November 2012 – February 2014*, for performance monitoring of bioventing.

c. Decommissioned on December 18, 2012.

d. Aquifer tube was broken and could not be sampled.

Data flags:

D	=	sample was diluted for analysis	Q	=	associated with out-of-limit quality control data
H	=	laboratory holding time exceeded before sample was analyzed	T	=	spike and/or spike duplicate sample recovery is outside control limits
J	=	concentration is estimated	U	=	undetected
N	=	spike sample outside limits	X	=	see hardcopy data report for further explanation
N/A	=	not applicable	Z	=	miscellaneous circumstances exist; see project file
NR	=	not reported			

Table 4-15. TPH-D Concentrations for Upriver Apatite Barrier Injection and Monitoring Wells

Date	N-200	N-201	N-202	N-203	N-204	N-205	N-206	N-207	N-208	N-209
4/1/2010	—	—	—	—	—	—	—	17 (U)	—	—
4/6/2010	—	3,500	—	3,600	—	3,200	—	—	—	2,200
6/24/2010	2,100 (X)	—	3,200 (X)	—	3,000 (X)	—	2,700 (X)	—	1,400 (X)	—
6/4/2014	856	2,800	—	—	—	—	—	—	—	—
6/7/2015	—	17 (U)	—	—	—	—	—	—	—	—
9/15/2015	—	15 (U)	—	—	—	—	—	—	—	—

Date	N-210	N-211	N-212	N-213	N-214	N-215	N-216	N-217	N-218	N-219
4/1/2010	—	17 (U)	—	17 (U)	—	17 (U)	—	17 (U)	—	17 (U)
4/6/2010	—	—	—	—	—	—	—	—	—	—
6/24/2010	70 (U)	—	70 (U)	—	—	—	—	—	—	—
6/25/2010	—	—	—	—	70 (U)	—	70 (U)	—	70 (U)	—
3/31/2014	70 (U)	—	—	—	—	—	—	—	—	—
6/4/2014	49.5 (U)	—	—	—	—	—	—	—	—	—
7/29/2015	—	590 (X)	—	—	—	—	—	—	—	—
9/15/2015	—	827	—	—	—	—	—	—	—	—

Date	N-220	N-221	N-222	N-223	N-224	N-225	N-226	N-227	N-228	N-229
3/31/2010	—	—	—	—	—	70 (U)	—	70 (U)	—	70 (U)
4/1/2010	—	17 (U)	—	17 (U)	—	—	—	—	—	—
6/25/2010	90 (U)	—	100 (U)	—	70 (U)	—	70 (U)	—	70 (U)	—
7/29/2015	—	—	—	—	—	—	—	—	—	16 (U)
9/18/2015	—	—	—	—	—	—	—	—	—	17 (U)

Table 4-15. TPH-D Concentrations for Upriver Apatite Barrier Injection and Monitoring Wells

Date	N-230	N-231	N-232	N-233	N-234	N-96A	N-347	N-348	N-349
3/31/2010	—	70 (U)	—	70 (U)	—	—	—	—	—
4/6/2010	—	—	—	—	—	—	17 (U)	3,800	17 (U)
6/25/2010	70 (U)	—	70 (U)	—	70 (U)	—	—	—	—
11/14/2010	—	—	—	—	—	200 (X)	—	—	—
1/18/2011	—	—	—	—	—	70 (U)	—	—	—
9/16/2011	—	—	—	—	—	70 (U)	80 (U)	80 (U)	70 (U)
9/20/2011	—	—	—	—	—	70 (U)	—	—	—
9/28/2011	—	—	—	—	—	—	80 (U)	80 (U)	80 (U)
10/13/2011	—	—	—	—	—	—	85 (U)	85 (U)	85 (U)
5/6/2012	—	—	—	—	—	—	70 (U)	70 (U)	—
8/27/2012	—	—	—	—	—	140	—	—	—
5/9/2012	—	—	—	—	—	—	—	—	91 J
5/6/2013	—	—	—	—	—	70 (U)	70 (U)		70 (U)
9/6/2013	—	—	—	—	—	70 (U)	70 (U)	70 (U)	70 (U)
6/5/2014	—	—	—	—	—	—	17 (U)	48.5 (U)	17 (U)
9/10/2014	—	—	—	—	—	—	140 (J)	65.5 (J,T)	—
9/11/2014	—	—	—	—	—	446 (T)	—	—	16 (U)
1/20/2015	—	—	—	—	—	52.1 (U)	—	—	—
6/7/2016	—	—	—	—	—	18 (U)	50 (T,U)	17 (U)	48.1 (T,U)
7/29/2015	—	—	—	—	—	161 (J,T)	—	—	—

Table 4-15. TPH-D Concentrations for Upriver Apatite Barrier Injection and Monitoring Wells

Date	N-230	N-231	N-232	N-233	N-234	N-96A	N-347	N-348	N-349	
9/22-28/2015	—	—	—	—	—	17 (U)	89.1 (J)	16 (U)	47.6 (U)	

Notes: Highest detected result or lowest nondetectable result for a calendar year is reported in this table.

Cells with "—" entry indicate well was not sampled for TPH-Diesel on the identified date

Orange shading indicates barrier injection well (deep).

Pink shading indicates barrier monitoring well (deep).

Yellow shading indicates barrier injection well (shallow).

J = estimated value

T = spike and/or spike duplicate sample recovery is outside control limits

U = undetected

X = see hardcopy data report for further explanation

Table 4-16. Breakdown of 100-NR-2 Remediation System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)															
	2000	2001[a]	2002[b]	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014[c]	2015
Design	—	—	—	—	—	447.9	—	—	—	20.5	31.0	—	0.6	0.0	0.0	0.0
Treatment system capital construction	—	—	—	—	—	161.9	922.6	—	—	316.2	(0.1)	(32.1)	0.0	0.0	0.0	0.0
Project support	96.3	183.5	219.4	133.0	329.7	416.5	284.4	79.8	10.7	278.5	276.5	178.9	133.3	284.2	173.9	170.8
Operations and maintenance	462.2	631.5	631.8	604.3	553.0	650.6	592.6	199.9	107.4	50.2	23.6	30.4	0.4	0.0	0.0	0.0
Performance monitoring	82.6	83.1	72.4	51.6	79.6	408.7	182.2	62.7	36.2	466.2	956.3	1,069.0	1,801.1	769.3	1,077.1	967.7
Waste management	131.6	112.5	100.0	45.4	27.4	7.6	13.0	43.4	8.9	3.6	0.5	2.3	0.0	0.0	0.0	0.0

Table 4-16. Breakdown of 100-NR-2 Remediation System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)															
	2000	2001[a]	2002[b]	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014[c]	2015
Field studies	—	—	—	—	—	—	—	—	—	874.1	1,228.3	119.5	(2.2)	68.0	0.0	0.0
Barrier maintenance	—	—	—	—	—	—	—	—	—	634.3	1,468.0	1,844.4	15.9	46.4	1,079.8	0.0
Totals	**$773**	**$1,011**	**$1,024**	**$834**	**$990**	**$2.093**	**$1,995**	**$386**	**$163**	**$2,644**	**$3,984**	**$3,212**	**$1,949**	**$1,168**	**$2,331**	**$1,139**

a. 2001 costs corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

b. 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

c. Barrier maintenance costs for 2014 were associated with preparation and procurement of chemicals for injections to extend the barrier but an adverse impact determination to a traditional cultural property has put further injections on hold until a memorandum of agreement is established for expansion of the PRB.

— = not available

PRB = permeable reactive barrier

5 References

07-AMCP-0266, 2007, "Completion of Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Milestone M-16-14A, "Complete Construction of a Permeable Reactive Barrier at 100-N" and Completion of Calendar Year 2007 Construction Activities at the 100-N Sequestration Barrier" (letter to J.A. Hedges, Washington State Department of Ecology from M.S. McCormick), U.S. Department of Energy, Richland Operations Office, Richland, Washington, August 31. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA05651004.

10-AMCP-0032, 2009, "Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision, DOE/RL-2009-54, Draft B" (letter to J.A. Hedges, Washington State Department of Ecology, and D.A. Faulk, U.S. Environmental Protection Agency from M.S. McCormick), U.S. Department of Energy, Richland Operations Office, Richland, Washington, December 18. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0095207.

11-AMCP-0002, 2010, "Non-Significant Change for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision, Hanford Site, Washington July 2010, Memo to File Regarding: Supplemental Actions for the In-Site Reduction/Oxidation Manipulation Barrier Performance for the 100-HR-3 Groundwater Operable Unit Interim Remedy" (letter to J.A. Hedges, Washington State Department of Ecology, and D.A. Faulk, U.S. Environmental Protection Agency from R.A. Holten), U.S. Department of Energy, Richland Operations Office, Richland, Washington, October 26. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1011290677.

36 CFR 800, "Protection of Historic Properties," *Code of Federal Regulations*. Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=512dbaad650fdbfc46c142ebd3103a9e&mc=true&node=pt36.3.800&rgn=div5.

36 CFR 800.3, "Initiation of the Section 106 Process."

36 CFR 800.4, "Identification of Historic Properties."

36 CFR 800.5, "Assessment of Adverse Effects."

40 CFR 143, "National Secondary Drinking Water Regulations," *Code of Federal Regulations*. Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=985db33061b8de66f19abcdc80ee0fe0&mc=true&node=pt40.23.143&rgn=div5.

BNWL-CC-1296, 1967, *Environmental Significance of Diesel Fuel Entering Columbia River at 100-N*, Pacific Northwest Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/pdf.cfm?accession=D196079022.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq., Pub. L. 107-377, December 31, 2002. Available at: http://epw.senate.gov/cercla.pdf.

DOE/RL-90-22, 1996, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196119051.

DOE/RL-96-84, 2003, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, Rev. 0-A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D1348764.

DOE/RL-99-51, 2000, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D8373878.

DOE/RL-2000-59, 2009, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0091138.

Modified by:

TPA-CN-353, 2010, *Change Notice for Sampling and Analysis Plan for Aquifer Sampling Test Tubes*, *DOE/RL-2009-59, Rev. 1*, dated May 4, U.S. Department of Energy, Richland Operations Office, and U.S. Environmental Protection Agency, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1006221269.

DOE/RL-2001-27, 2014, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0083571H.

DOE/RL-2004-21, 2004, *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D4953894.

DOE/RL-2004-56, 2004, *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D7004849.

DOE/RL-2005-18, 2005, *Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA088495.

DOE/RL-2005-93, 2006, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area,* Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04193451.

DOE/RL-2005-96, 2006, *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit*, Rev. 0, Reissue, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA02781523.

DOE/RL-2006-20, 2006, *The Second CERCLA Five-Year Review Report for the Hanford Site*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04570094.

DOE/RL-2006-75, 2008, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump-and-Treat System*, Rev. 1, Reissue, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0812030152.

DOE/RL-2008-46-ADD1, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084374.

DOE/RL-2008-46-ADD5, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1105031083.

DOE/RL-2008-46-ADD2, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1003311065.

DOE/RL-2009-40, 2010, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084375.

DOE/RL-2009-41, 2009, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1002260413.

DOE/RL-2009-92, 2009, *Report on Investigation of Hexavalent Chromium in the Southwest 100-D Area*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1110180067.

DOE/RL-2010-29, 2010, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1010051004.

DOE/RL-2010-68, 2011, *Jet Injection Design Optimization Study for 100-NR-2 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1102231040.

DOE/RL-2010-95, 2014, *Remedial Investigation/Feasibility Study for 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at:

http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0083383H.
http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0083382H.
http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0083381H.
http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0083380H.

DOE/RL-2010-97, 2011, *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, Draft A, U.S. Department of Energy, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093615.

DOE/RL-2011-25, 2011, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093679.

DOE/RL-2011-111, 2012, *Proposed Plan for Remediation of the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0090582.

DOE/RL-2012-15, 2013, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0088368.

DOE/RL-2014-25, 2014, *Calendar Year 2013 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0083709.

DOE/RL-2015-05, 2015, *Calendar Year 2014 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080173H.

DOE/RL-2015-20, 2015, *Annual Operations Monitoring Report for UPR-100-N-17: March 2014 – February 2015*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080062H.

DOE/RL-2016-09, 2016, *Hanford Site Groundwater Monitoring Report for 2015*, in publication, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2016-34, 2016, *Annual Operations and Monitoring Report for UPR-100-N-17: March 2015 – February 2016*, pending, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

ECF-HANFORD-12-0078, 2013, *Assessment of the River Protection Objective: Calculation for Calendar Year 2011 (CY2011)*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079682H.

ECF-HANFORD-13-0028, 2014, *Columbia River Stage Correlation for the Hanford Area*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079652H.

ECF-HANFORD-15-0003, 2015, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2014 (CY2014) Hanford Site Groundwater Monitoring Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079509H.

ECF-HANFORD-16-0060, 2016, *Description of Groundwater Calculations and Assessments for the Calendar Year 2015 (CY2015) 100 Areas Pump-and-Treat Report*, pending, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-HANFORD-16-0061, 2016, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2015 (CY2015) Hanford Site Groundwater Monitoring Report*, pending, CH2M HILL Plateau Remediation Company, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=81.

EPA/AMD/R10-00/122, 2000, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

EPA/ROD/R10-96/134, 1996, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0078950H

EPA/ROD/R10-99/112, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0078951H

EPA, Ecology, and DOE, 2009, *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0096029.

EPA, 2010, *U.S. Department of Energy 100-NR-1 and NR-2 Operable Units Hanford Site – 100 Area Benton County, Washington Amended Record of Decision, Decision Summary and Responsiveness Summary*, U.S. Environmental Protection Agency, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084198.

NAVD88, 1988, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: http://www.ngs.noaa.gov/.

National Historic Preservation Act of 1966, Pub. L. 89-665, as amended, 16 USC 470, et seq. Available at: http://www.achp.gov/docs/nhpa%202008-final.pdf.

PNL-6456, 1988, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford: Volume 1 – Evaluation Methods and Results*, Vol. 1, Pacific Northwest Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196006954.

PNNL-16891, 2007, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16891.pdf.

PNNL-17429, 2008, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0810240396.

PNNL-18784, 2009, *Hanford 100-D Area Biostimulation Treatability Test Results*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093406.

PNNL-19572, 2010, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization, Final Report*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19572.pdf.

PNNL-SA-70033, 2009, *100-NR-2 Apatite Treatability Test FY09 Status: High Concentrations Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization: Interim Report*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-SA-70033.pdf.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. Available at: http://www.epa.gov/epawaste/inforesources/online/index.htm.

SGW-42305, 2009, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0911170654.

SGW-43616, 2011, *Functional Design Criteria for the 100-HX Pump and Treat System*, Rev. 4, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081275H.

SGW-46279, 2012, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0087245.

SGW-49370, 2011, *Columbia River Pore Water Sampling in 100-N Area, December 2010*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080429H.

SGW-53543 *Automated Water Level Network Functional Requirements Document,* Rev. 1 CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-54209, 2013, *Systematic Method for Evaluating the Length of the Hanford Reach of the Columbia River Shoreline that is Protected from Further Discharges of Chromium from the 100 Area Operable Units (OUs)*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0087569.

SGW-56970, 2015, *Performance Report for the 2011 Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079642H.

SGW-58416, 2015, *Persistent Source Investigation at 100-D Area*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0082018H.

UNI-228, 1985, *Oil Spill Prevention, Control, and Countermeasures Plan*, Rev. 4, UNC Nuclear Industries, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=E0021445.

WAC 173-340, "Model Toxics Control Act—Cleanup," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340.

WCH-323, 2008, *Sampling and Analysis Instruction for Installation of UPR-100-N-17 Bioremediation Wells and Performance of Bioventing Pilot Tests*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://www.osti.gov/scitech/servlets/purl/945222.

WCH-490, 2011, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093690.

WCH-600, 2014, *Annual Operations and Monitoring Report for UPR-100-N-17: November 2012 – February 2014*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0085479.

WHC-C-89-047-100N-20, 1989, *Critique Report, 184-N Powerhouse Diesel Oil Leak (April 26, 1989)*, Rev. 2, Westinghouse Hanford Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079653H.

WHC-SD-EN-TI-251, 1994, *100-N Area Technical Baseline Report*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196229412.

This page intentionally left blank.